Risk Assessment, Feasibility Study, and Source Control Evaluation Operable Unit 4 Swan Island Upland Facility Portland, Oregon

Prepared for:
Port of Portland

April 23, 2012
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1.0 Introduction

1.1 Purpose and Scope

This report presents the risk assessment, feasibility study (FS), and source control evaluation (SCE) for Operable Unit 4 (the Facility or OU4) at the Swan Island Upland Facility (SIUF) in Portland, Oregon. Figures 1 and 2 show the location of OU4. The general scope of each study is summarized as follows:

- Streamlined Baseline Human Health Risk Assessment (HHRA) – The streamlined HHRA was conducted in accordance with the protocol for performing risk assessments under Oregon Administrative Rules (OAR) 340-122-084, Oregon Department of Environmental Quality (DEQ) risk assessment guidance documents (DEQ, 2000 and 2003), and the *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual* (U.S. Environmental Protection Agency [EPA], 1989), as appropriate.
- Streamlined FS – The streamlined FS was prepared in accordance with OAR 340-122-0085 and OAR 340-122-0090, guidance from the EPA (1988), and the Oregon DEQ Guidance for Conducting Feasibility Studies (DEQ, 1998).
- SCE – The SCE was performed in response to a request by the DEQ to identify, evaluate, and control sources of contamination that may reach the Willamette River consistent with the DEQ-EPA Portland Harbor Joint Source Control Strategy (JSCS; DEQ/EPA, 2005).

The Port of Portland (Port) is performing a Remedial Investigation/ Feasibility Study (RI/FS) for the SIUF. The SIUF was previously referred to as the Swan Island Portland Ship Yard and identified by the DEQ as Environmental Cleanup Site Information (ECSI) site 271. The RI is being performed in accordance with the November 2, 2000 RI/FS Work Plan for the Portland Shipyard (RI/FS Work Plan; Bridgewater Group, 2000).

1.2 Objective

The objectives of the studies within this report are listed below.

- Streamlined HHRA – Identify the baseline quantitative potential risk to human health resulting from chemicals of potential concern (COPC) present at OU4.
- Streamlined FS – Recommend a remedial action to address unacceptable risk identified by the baseline HHRA.
- SCE – (1) Identify potential sources of contamination at OU4; (2) evaluate the potential sources identified; and (3) if necessary, recommend controls of potential sources of contamination that may adversely impact the Willamette River.

1.3 Regulatory Framework

This work is being conducted under an agreement between the Port and DEQ – Voluntary Agreement for Remedial Investigation, Source Control Measures, and Feasibility Study – dated July 24, 2006 (Agreement). For the purposes of the work conducted under the Agreement, the SIUF has been divided into four OUs designated as follows:

- OU1 – Approximately 57 acres of upland property owned by Shipyard Commerce Center LLC (formerly Cascade General), and operated as the Vigor Marine (Vigor) Ship Repair Yard and formerly known as the Portland Shipyard (PSY).
- OU2 – Approximately 24 acres of upland property owned by the Port south of N. Channel Avenue formerly referred to as the N. Channel Avenue Fabrication site.
- OU3 – Approximately 2.5 acres of upland property owned by the Port on N. Lagoon Avenue that includes the property at 5420 N. Lagoon Avenue and the adjacent property to the north that provides access to Berths 308 and 309.
- OU4 – Approximately 7.8 acres of upland property between OU1 and OU2. Until 2008, OU4 was part of OU2, but was designated a separate OU to facilitate the sale of the property from the Port to Shipyard Commerce Center LLC.

Figure 2 shows the locations of the OUs.

Consistent with the Agreement, the SIUF does not include: (1) adjacent sediments, submerged lands, and submersible lands up to the ordinary line of high water (OLHW) of the Willamette River; (2) the remaining portions of the Swan Island peninsula; (3) dry docks owned, operated, and maintained by Vigor; (4) storm water conveyance systems owned, operated, and maintained by Vigor under National Pollutant Discharge Elimination System (NPDES) General Permit 1200-Z; (5) waste discharges permitted under NPDES Permit No. 101393, including treated ballast water from the ballast water treatment plant (BWTP), treated dry dock storm water and process wastewater, and untreated non-contact cooling water from the dry docks ballast water treatment plant; (6) the Port's Berth 311 upland site; and (7) any other activities or operations over which the Port has no control, associated with Vigor or its subcontractors.

1.4 Report Organization

Background information is provided in Sections 2 and 3, and soil, groundwater, storm water solids, and storm water data are summarized in tables in Appendix A. A report presenting recent surface soil sampling results is presented in Appendix B. The baseline risk assessment, focused FS, and SCE are presented in Sections 4 through 6, respectively. Supporting information is presented in tables, figures, and appendices.

2.0 Facility Background

2.1 Facility Description

Figure 2 shows the layout of OU4. The property covers approximately 7.8 acres on the south side of Swan Island, south of N. Channel Avenue. The bulk of the property consists of a paved parking lot with landscaped islands. None of OU4 is adjacent to the bank of the Willamette River. OU4 is relatively flat with land surface elevations generally ranging between 30 and 34 feet (NGVD 29 with the 1947 adjustment; Hahn and Associates, 2002).

2.2 Historical Facility Use

OU4 was developed in the 1920s, and has been used for a variety of light industrial uses since, including:

- 1923 to 1931 – Development of Swan Island;
- 1931 to 1941 – Portland Airport;
- 1942 to 1949 – Storage area/support services for Military-era ship building and related industries;
- 1950 to 1977 – Material storage; and
- 1977 to Present – Paved parking lot.

Figure 3 identifies historical features relevant to potential for contamination of the Facility.

The Port acquired Swan Island, including the area now occupied by OU4, from the Swan Island Real Estate Company on January 3, 1922. The Port continuously owned the property from 1922 to 2008.

The Port developed Swan Island beginning in 1923, when the main navigation channel of the Willamette River was relocated to the west side of the island. River sediments dredged as part of the project were deposited on Swan Island to raise the surface elevation and construct a causeway connecting the island to the eastern shore of the river. This filling prepared the island for development into the first Portland airport. Airport construction was completed and operations started in 1931. The airport operated until 1941, when it was relocated to northeast Portland. Based on historical research, airport facilities that were located on OU4 were a paved runway and cinder taxiways.

Between 1942 and 1949, the United States used OU4 to support military-era ship building and related industries. Electrical substations that may have contained equipment with polychlorinated biphenyls (PCBs) were installed during this period. One substation, designated as substation R, was located on OU4. A second substation (substation A) was located immediately adjacent to OU4 on OU2. As shown on Figure 3, all or part of four buildings were located on OU4, including the mold loft (Building #3), oxygen house (Building #5), machine shop (Building #9) and boiler erection building (Building #21). The mold loft was a

45,500-square-foot, two-story building with rail service and loading dock that was used as a template layout area for shaping steel. The oxygen house was a small structure where oxygen was stored. The machine shop was a 37,000-square-foot, one-story structure with a concrete floor and spur track where tools and parts were machined. The boiler erection building was a two-story structure where vessel boilers were constructed. Most of the mold loft and machine shop were located on adjacent parcels of property to the north of OU4. In addition to the buildings, steel plate and shaped steel pieces were stored on OU4. Multiple rail spur tracks crossed OU4.

Between 1950 and 1977, OU4 was primarily open, graded soil with railroad spurs used for material receiving and storage. The main parking lot was constructed in 1977. It has been used as a parking lot for shipyard workers since 1977. The only additional use was the temporary staging of new trucks and trailers by Daimler AG Trucks (formerly Freightliner LLC) on a portion of the parking lot under a lease from the Port.

Additional information related to the operating history of OU4 is provided in the supplemental preliminary assessment (PA; Ash Creek Associates, Inc. [Ash Creek], 2006).

2.3 Current Facility Use

Figure 4 is a site plan overlain on a 2008 aerial photograph showing the current Facility use. The parcel of property is paved with asphalt-concrete. There are currently no structures or buildings on OU4.

Between OU4 and the top of the river bank is 2.7 acres of vacant land that is a part of OU2. The vacant property is covered with compacted gravel.

2.4 Storm Water Handling

Figure 5 shows the storm water system at OU4. The main parking lot drains to a series of inlets that discharge through an 18-inch corrugated metal pipe to the Willamette River (Ash Creek, 2008a). The storm water outfall is designated as WR-399 by the City of Portland. This is the only known, active storm water outfall that is associated with OU4. Flow and dye testing were performed on the main parking lot drainage system. The testing results confirmed that eight inlets drain to the main storm line connected to outfall WR-399. The testing results also determined that an inlet/catch basin (type of feature not field verified), located near the northwest boundary of OU4 does not drain to WR-399; the point of discharge for this feature was not definitively determined but is believed to discharge from property currently comprising Cascade General's site that is being addressed by Cascade General under its May 8, 2006 storm water letter agreement with DEQ.

2.5 Upland Investigations

Since 2000, the Port has completed RI activities throughout the SIUF, including Phase I RI soil and groundwater investigations, Phase II RI groundwater monitoring well installation, four quarters of groundwater sampling, and five years of annual groundwater sampling. The Port and others also performed OU-specific investigation activities. Shipyard Commerce LLC performed sampling of soil and groundwater on OU4 prior to purchase of the property from the Port. The Port completed surface soil sampling at the former substations and at locations sampled by Shipyard Commerce LLC. During maintenance of the storm water system, the Port conducted sampling of storm water and storm water solids.

The following sections summarize the previous investigations for OU4. Figure 6 is a comprehensive sample location plan, and analytical data are listed in Tables A-1 through A-23 in Appendix A.

2.5.1 Pre-RI Investigation

In 1998, surface (0 to 2 feet below the ground surface [bgs]) and subsurface (between 14 and 22 feet bgs) soil samples were collected at each of 16 locations on the SIUF to establish baseline conditions prior to the sale of the shipyard to Shipyard Commerce Center LLC. One boring (designated Boring 7) was located on OU4. In addition, Boring 1 was located immediately adjacent to OU4. The soil samples were analyzed for petroleum hydrocarbons, PCBs, and metals. The results of the assessment are summarized in the RI/FS work plan (Bridgewater Group, 2000). A summary of the soil data is included in Table A-1 in Appendix A.

2.5.2 Soil Investigations

Soil data were collected during sampling of former electrical substations in 2007, a due diligence investigation in 2008, and in 2009, follow-up sampling requested by the DEQ. The following sections summarize the soil data collection activities. Figure 6 shows the soil sample locations.

Substation Sampling. Soil samples were collected from two former substation locations (Substations A and R) formerly located on or adjacent to OU4 (Ash Creek, 2007). Four surface soil samples were collected at the corners of a 30- by 30-foot grid at each former substation location. The soil samples were analyzed by the total petroleum hydrocarbons (TPH) identification method (NWTPH-HCID) and by EPA Method 8082 for PCBs. Results are presented in Tables A-2 and A-3 in Appendix A. No TPH or PCBs were detected in the soil samples.

2008 Due Diligence Investigation. As part of pre-acquisition due diligence, URS Corporation (URS) completed a subsurface investigation (on behalf of Shipyard Commerce LLC) to assess the potential for environmental impacts to soil beneath OU4 (Port, 2008). Shallow and deep borings were completed in May 2008. Four soil samples were collected from each deep boring (nominally at 5, 50, 75, and 100 feet bgs) and three soil samples were collected from each shallow boring (nominally at 5 feet bgs, soil water interface, and 40 feet bgs). The soil samples were analyzed for TPH (as gasoline, diesel, and oil), PCBs, polycyclic aromatic hydrocarbons (PAHs), tributyl tin (TBT), volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and metals (including arsenic, barium, chromium, copper, lead, mercury, nickel, and zinc). The sample results are presented in Table A-4 in Appendix A.

2009 Surface Soil Sampling. At the request of DEQ, surface soil samples were collected at the location of eight of the borings completed by URS. The soil samples were analyzed for TPH, metals, and PAHs. A report documenting the investigation is included in Appendix B. Results are presented in Tables A-5 through A-7 in Appendix A.

2.5.3 Groundwater Investigations

Grab groundwater samples were collected during the due diligence investigation. In addition, groundwater monitoring was conducted during multiple investigations at the SIUF between 2001 and 2007. Figure 6 shows the locations of the groundwater samples.

2008 Due Diligence Investigation. As part of the pre-acquisition due diligence investigation conducted by URS, grab groundwater samples were collected at the maximum depth of each boring using a temporary well screen. The groundwater samples were analyzed for TPH (as gasoline, diesel, and oil), PCBs, PAHs, TBT, VOCs, SVOCs, and metals. The sample results are presented in Table A-8 in Appendix A.

SIUF RI Groundwater Investigation. In December 2001, the Port installed 11 monitoring wells at the SIUF (MW-1 through MW-11). None of the wells were located on OU4, but the three nearest wells are MW-7 and MW-8 located northwest of OU4, and MW-11 located southeast of OU4. One year of quarterly sampling of the monitoring well network was conducted (Bridgewater, 2001 and 2002). For the quarterly monitoring, groundwater samples were analyzed for metals, TBT, VOCs, and PAHs. In addition, periodic sampling for selected analytes was conducted through 2007. The shift from quarterly to periodic sampling coincided with the implementation of low flow sampling methods, as requested by DEQ, to reduce sample turbidity and provide more representative results. The most recent groundwater monitoring report discusses groundwater sampling (Bridgewater Group, 2008). The monitoring well sample results are presented in Tables A-9 through A-13 in Appendix A.

2.5.4 Storm Water Investigation

In 2008, the Port removed solids from each of the inlets and jetted the lines between the inlets and outfall WR-399 (Ash Creek, 2008b). These activities were completed as part of the sale of the OU4 parking lot to Shipyard Commerce Center LLC. As part of the sale, the Port and Shipyard Commerce Center LLC agreed that after the storm water management system connected to outfall WR-399 was cleaned out, sampled and analyzed, Vigor (operator of the shipyard) would assume responsibility for completing any further storm water system evaluation and storm water remedial action. A representative composite sample was collected from the dry solids (removed from the storm water inlets) and submitted for chemical analysis. Following the cleanout of the conveyance system, a whole-water grab sample was collected directly from Outfall WR-399 during a representative storm event (on June 3, 2008). The storm event met the Storm Event Criteria and Selection outlined in the JSCS (DEQ/EPA, 2005).

The solids and storm water sample were analyzed for TPH (as gasoline, diesel, and oil), PCBs, phthalates, PAHs, TBT, and metals (including aluminum, antimony, arsenic, cadmium, chromium, copper, lead, mercury, manganese, nickel, selenium, silver, and zinc). The sample results are presented in Tables A-14 through A-23 in Appendix A.

2.6 Level I Scoping Ecological Risk Assessment

In February 2006, a Level I Scoping Ecological Risk Assessment (ERA) was conducted for OU2 (NewFields, 2006). At that time, OU4 was a part of OU2 and the Level I Scoping ERA included OU4. The Level I Scoping ERA concluded that the upland portion of the Facility, particularly the paved parking lot that is now OU4, provided no habitat and therefore no risk to ecological receptors. A Level II Screening ERA was recommended for the riverbank portions of OU2, but these areas are not on OU4. No further action was recommended for the portion of OU2 that is now OU4.

3.0 Conceptual Site Model

The Conceptual Site Model (CSM) presented in this section was developed from the results of the RI and subsequent data collection activities summarized in Section 2.0. The supplemental PA (Ash Creek, 2006) also provides specific details on the site history.

3.1 Geology and Hydrogeology

3.1.1 Geology

Regional Geology. The SIUF is located in the Portland Basin, a bowl-like structure bounded by folded and faulted uplands. The basin has been filled with up to 1,400 feet of alluvial and glacio-fluvial flood deposits. These sediments overlie older (Eocene and Miocene) rocks, including the Columbia River Basalt Group (CRB), Waverly Heights Basalt, and older marine sediments. Regional geologic units present beneath the Facility (from the ground surface downward) include Recent Fill (primarily dredged river sediment); fine-grained Pleistocene Flood Deposits and Recent Alluvium (undifferentiated); coarse-grained Pleistocene Flood Deposits (gravels); Upper Troutdale Formation; Lower Troutdale Formation/Sandy River Mudstone; and CRB.

Local Geology. Phase I and II investigations performed at the SIUF characterized geologic conditions to approximately 40 feet bgs. The subsurface soils beneath the SIUF are mixtures of silt, sandy silt, silty sand,

sand, and sand with gravel. In general, sand and occasional gravel are encountered to a depth of approximately 20 feet bgs. These materials represent the Willamette River dredged materials that were placed on Swan Island when it was reconfigured and raised in elevation in the 1920s. Underlying the fill is recent alluvium associated with the original Swan Island, consisting of variable mixtures of silt, sandy silt, silty sand, and sand.

3.1.2 Hydrogeology

Regional Hydrogeology. The major hydrogeologic units found in the area, proceeding from uppermost to lowermost, are Fill, Fine-grained Facies of Flood Deposits, and Recent Alluvium (FFA); Coarse-grained Flood Deposits and Upper Troutdale Formation (CGF); Lower Troutdale Formation/Sandy River Mudstone; and CRB. Of these, the FFA and CGF are the two hydrogeologic units that are relevant to the SIUF. The FFA ranges in thickness from 30 to 100 feet; it is the primary unit of importance in defining the interactions between upland groundwater and the river. The distribution of textures – and thus groundwater flow properties of the unit – varies both vertically and horizontally by location. Typical hydraulic conductivities can range over several orders of magnitude, depending upon whether the unit contains silt and clay, silty sand, or sand. The CGF has an overall thickness in the range of 100 feet. The CGF unit may act as a preferential groundwater flow pathway to deeper units and for deeper groundwater flow to the river where it is present adjacent to the river.

Local Hydrogeology. Shallow groundwater occurs under water table conditions at the SIUF. The depth to groundwater ranges from approximately 18 to 30 feet bgs (Bridgewater Group, 2008). Shallow groundwater is recharged by the infiltration of precipitation that falls on Swan Island. Shallow groundwater discharges to the Willamette River and Swan Island Lagoon. Beneath OU4, the groundwater flow direction is expected to be southwesterly, toward the Willamette River.

Groundwater elevations near the shorelines of the Willamette River and Swan Island Lagoon fluctuate in response to diurnal tidal cycles and seasonal changes in Willamette River elevations. Groundwater monitoring performed between December 2001 and December 2005 found that groundwater elevations in wells installed near the shoreline fluctuated approximately 8 feet. Inland, toward the middle of Swan Island, the response to changes in river elevations is less pronounced, with observed fluctuations of less than 1 foot.

Surface Water. There are no surface waters on the Facility. The Willamette River is located 100 to 150 feet southwest of OU4 (see Figure 2). Storm water handling at the Facility is discussed in Section 2.4.

3.2 Nature and Extent of Contamination

Based on historical reviews and investigations conducted at the Facility, the chemicals of interest (COI) in soil and groundwater are petroleum hydrocarbons, PAHs, PCBs, VOCs, phthalates, TBT, and metals.

COI data are listed in the tables in Appendix A. Sample locations are shown on Figure 6. The majority of samples analyzed were at background concentrations or below detection limits. The most frequently detected COI were PAHs and metals.

3.3 Beneficial Land and Water Use

A land use evaluation and a beneficial water use evaluation were completed as part of the SIUF RI (Bridgewater Group, 2006). Conclusions of the land and water use evaluations are summarized below.

The current and reasonably likely future land use for the SIUF is industrial. The SIUF is currently zoned industrial and lies within the City of Portland Industrial Sanctuary and Swan Island Plan District. The SIUF is expected to continue to be used for industrial purposes, consistent with goals and policies stated in the City's Comprehensive Plan.

The only current and reasonably likely future beneficial groundwater use at the SIUF is discharge to surface water. Other beneficial uses of groundwater on the SIUF are unlikely because: a public water supply system already exists and is the source of water supply to the OUs; there is no trend toward groundwater being developed as a source of water supply in the area; the owners of properties that make up the SIUF have indicated that they have no plans for future use of groundwater; and the public water suppliers, including the City, have no plans to develop groundwater on or near the SIUF to meet future increases in water demand.

The Willamette River is less than 200 feet from the boundary of the Facility. It is used mainly for habitat (e.g., anadromous and resident fish species), commercial/industrial activities (e.g., navigation), and recreational activities (e.g., boating, sport fishing). Also, local American Indian tribes have fishing rights on the lower Willamette River.

3.4 Human Health Chemicals of Potential Concern

Investigations at the Facility included chemical analysis of up to 56 soil samples (see Appendix A). These data are of sufficient quality for use in a risk assessment. Except for recharge to the Willamette River, there are no exposure pathways to groundwater. Thus, groundwater is evaluated in the SCE in Section 6. The risk assessment in Section 4 includes soil only. A screening of the soil chemical data was completed to identify human health COPC in accordance with DEQ risk assessment guidance (DEQ, 2000). In general, the soil screening process used assumptions about exposure and toxicity that are more conservative than used in the subsequent risk calculations. This approach assures that chemicals that may contribute small but significant portions to overall risk are not left out. Primary conservative approaches used for the human health COPC screening include:

- Residential screening levels for soil; and

- Use of diesel screening level for residual petroleum hydrocarbons.

The soil human health COPC screening is presented in Table 1. The screening identified the following human health COPC: arsenic, benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene.

4.0 Baseline Human Health Risk Assessment

This section describes the scope and results of the baseline HHRA for the Facility. The baseline HHRA conforms to the protocol for performing risk assessments under OAR 340-122-084; DEQ's *Guidance for Conduct of Deterministic Human Health Risk Assessments* (DEQ, 2000); and DEQ's guidance for risk-based decision making (RBDM) for the remediation of petroleum-contaminated sites (DEQ, 2003). The baseline HHRA evaluates the magnitude of adverse impacts to human health associated with actual or potential exposure to Facility-related COPC.

The baseline HHRA quantitatively evaluated the complete exposure pathways for the Facility. In accordance with EPA and DEQ guidance, this baseline HHRA included: exposure assessment, toxicity assessment, risk characterization, and an uncertainty analysis.

4.1 Exposure Assessment

The objectives of the exposure assessment are to:

- Identify potentially exposed populations;
- Identify potentially complete exposure pathways; and
- Measure or estimate the magnitude, duration, and frequency of exposure for each receptor (or receptor group).

Figure 7 shows the human health CSM for the Facility. The CSM provides the framework for assessing potential exposure pathways to be considered in the risk assessment. To be considered complete, an exposure pathway must have: (1) an identified source of COPC; (2) a release/transport mechanism from the source; and (3) a receptor to whom contact can occur. The following summarizes the analysis of these factors, which were used to develop the CSM.

4.1.1 Potentially Exposed Populations

Populations considered for potential exposure include residents; occupational, construction, and excavation workers; recreational users; and trespassers. Potential for exposure of these populations was evaluated as follows:

- Residents: The Facility is industrial and will likely remain industrial, so there is no direct exposure to residents. The beneficial water use analysis indicates that the only current or reasonably likely future use of groundwater is recharge to the Willamette River. Migration of COPC to surface water will be addressed in the SCE in Section 6. Therefore, there is no indirect exposure to residents.
- Occupational Workers: Occupational workers could be exposed to soil in the future (the existing parking lot prevents current exposure to occupational workers). The only potential exposure to groundwater is indirect (i.e., volatilization), but there are no volatile COPC, so this pathway is incomplete.
- Construction and Excavation Workers: Construction and excavation workers could be exposed to soil in future construction projects. Given the depth to groundwater (greater than 18 feet bgs), there are no direct exposures of workers to groundwater. Indirect exposure (i.e., volatilization) is possible, but there are no volatile COPC, so this pathway is incomplete.
- Recreational Users: The Facility is located in an industrial area where access is controlled, so there would be no direct exposure for recreational users. Potential exposures to recreational users of the river will be addressed by the SCE (in Section 6) and Portland Harbor risk assessment.
- Trespassers: The Facility is located in an industrial area where access is controlled. Trespassers are not considered to be a potentially exposed population.

In summary, potential receptors quantitatively evaluated in this baseline HHRA are occupational, construction, and excavation workers.

4.1.2 Potentially Complete Exposure Routes

The following lists possible exposure pathways with discussion of rationale for inclusion or exclusion of each pathway:

- Direct Contact: Direct contact with soil containing COPC is possible for occupational, construction, and excavation workers. Direct contact may include incidental ingestion, skin contact, or inhalation of vapors and dust.
- Outdoor Air: Inhalation of dust is included in the direct contact pathway. Because there are no volatile COPC, this pathway is otherwise incomplete.
- Indoor Air: This pathway is incomplete because there are no volatile COPC.
- Groundwater Use: Groundwater is not used and is not reasonably likely to be used, so there are no direct groundwater exposures. Indirect exposures resulting from migration of groundwater to surface water are addressed by the SCE in Section 6.
- Surface Water: Migration of groundwater to the river and storm water are addressed in the SCE in Section 6, so no surface water pathways are evaluated in this baseline HHRA.

- Leaching to Groundwater: Leaching to groundwater is assessed in the SCE in Section 6.

Based on the above discussion, the exposure pathway evaluated for receptors in this baseline HHRA is:

- Direct Contact: Incidental ingestion of, dermal contact with, and inhalation of dust from soil (occupational, construction, and excavation workers).

4.1.3 Soil Exposure Point Concentrations

Exposure point concentrations (EPCs) representative of chemical concentrations in soil and groundwater were calculated to compare to toxicity criteria. The EPCs for the Facility COPC were derived from data obtained from sampling, as discussed below. Appendix A contains tables listing the data used for the EPC calculations.

Representative Soil Data Sets. In selecting data sets representative of the potential exposure pathways and receptors, consideration was given to lateral extent, vertical extent, and time period of data collection.

For lateral extent, a receptor exposure area was defined representing the area typically occupied by a potential receptor. For an industrial area, each business or typical use area is a potential exposure area because it is reasonable to assume that a typical person has only one full-time occupation and, therefore, one place of business. Because OU4 has a single use (parking lot), it was treated as a single exposure area.

For vertical extent, representative data were selected as follows:

- Occupational workers are typically exposed only to surface soil, so soil data in the depth range of 0 to 3 feet were used to evaluate occupational worker exposure.
- Construction and excavation workers could be exposed to deeper soil. Construction and excavation workers were evaluated considering data sets from both 0 to 3 feet and 0 to 15 feet.

The following summarizes the data sets used in the soil EPC calculations:

- Occupational Worker, Direct Contact: Data from soil samples collected within 3 feet of the ground surface were used.
- Construction and Excavation Workers, Direct Contact: Two data sets were evaluated: (1) Data from soil samples collected within 3 feet of the ground surface; and (2) Data from soil samples collected within 15 feet of the ground surface.

Representative Concentrations. Risks are evaluated based on the reasonable maximum exposure (RME) and the central tendency (CT). In accordance with DEQ guidance, the 90-percent upper confidence limit (90% UCL) on the arithmetic mean concentration of COPC in each environmental medium of concern was used to evaluate the RME scenario, while the arithmetic mean was used to evaluate the CT scenario. The RME scenario is intended to be a conservative estimate of potential exposure, while the CT is intended to be a more realistic exposure scenario. Using both the RME and CT allows for a range of potential risk and hazard estimates.

Soil EPCs. Table 2 summarizes the results of the EPC calculations. The methods for calculating EPCs in soil for direct contact pathways were as follows:

- A data set was created for each COPC and for each receptor and pathway discussed above. Only COPC with at least one detection within the data set were included in the quantitative evaluation.
- For each data set, EPA's ProUCL Version 4.00.04 (EPA, 2009) was used to obtain data distribution evaluations and estimates for various statistical results including the mean and 90% UCL. The ProUCL package includes computation methods (e.g., Kaplan-Meier) that can be used with non-detect values. Input and output from the ProUCL calculations are presented in Appendix C.
- The ProUCL output included the mean value of the detected concentrations and the mean value assuming one-half the detection limit for non-detect values. For data sets with non-detect values, the latter value is reported as the mean in Table 2.
- The CT and RME values were selected as follows:
  - CT – The calculated mean value was used.
  - RME – The calculated 90% UCL was used.

4.1.4 Exposure Parameters

Exposure parameters consist of characteristics of the exposed populations (e.g., body weight, lifetime, ingestion rates, breathing rates, etc.), characteristics of the chemicals (e.g., volatility, water/soil partitioning), or characteristics of the site conditions (e.g., depth to groundwater). The exposure parameters are combined to convert the EPCs determined in Section 4.1.3 to doses experienced by the receptors. This baseline HHRA uses DEQ default exposure parameters for the purpose of calculating baseline risk.

4.2 Toxicity Assessment

The objectives of the toxicity assessment are to evaluate the inherent toxicity of the COPC and to identify and select toxicological measures for use in quantifying the significance of the exposure. The toxicity values are then combined with the EPCs and exposure factors to estimate site hazards and risks. The use of default parameters allows for the toxicity assessment and HHRA process to be streamlined, as described in Section 4.3. This baseline HHRA uses default toxicity parameters embodied in risk-based concentrations (RBCs). The RBCs used are from DEQ's RBDM guidance (DEQ, 2003; RBC spreadsheet updated September 15, 2009). Table 3 lists the RBCs for each of the pathways and receptors discussed in Section 4.1.

4.3 Risk Characterization

Risk characterization is the process of comparing the chemical intake by a receptor to the toxicity of the chemical. This comparison is expressed either as a hazard index (HI; non-carcinogens) or an excess lifetime risk of cancer (carcinogens). Potential hazards and risks were calculated using the RBC Method as described below.

4.3.1 Non-Carcinogenic Effects

There are no non-carcinogens identified as COPC.

4.3.2 Carcinogenic Effects

For each carcinogen, the excess lifetime cancer risk estimate is computed as follows:

[5] Risk = D x SF

where:

D = Dose of chemical experienced by the receptor
SF = Carcinogenic slope factor

and:

[6] D = EPC x EF

[7] RBC = Risk*/(EF x SF)

where:

EPC = Exposure point concentration (see Section 4.1); listed in Table 2
EF = Exposure factors for carcinogens combined in accordance with DEQ and EPA guidance (default factors used for this baseline HHRA)
RBC = Risk-based concentration determined in accordance with DEQ guidance (DEQ, 2003) and listed in Table 3
Risk* = Acceptable excess lifetime cancer risk for individual chemicals (in accordance with OAR 340-122-115, 1 x 10^{-6})

Substitute for dose in equation [5] using equation [6]. Solve equation [7] for SF and substitute the result in equation [5]. The result is equation [8]:

[8] Risk = (EPC x Risk*)/RBC

For simultaneous exposure to multiple chemicals, individual excess risk estimates are summed to provide pathway, media, and receptor total excess risk estimates. Combining potential cancer risks as a result of exposure to multiple chemicals through multiple exposure pathways assumes that each COPC exerts its effect independently (i.e., there is no synergism or antagonism).

OAR 340-122-115 considers $1x10^{-5}$ to be the acceptable risk level for combined risk from multiple carcinogens and/or multiple pathways.

Table 4 presents the results of the carcinogenic excess lifetime risk estimates. The results of the carcinogenic risk estimates are summarized as follows:

- Potential unacceptable risk was identified for occupational worker direct contact with soil containing arsenic. The estimated excess lifetime risks for this scenario are $3x10^{-6}$ for CT and $5x10^{-6}$ for RME.
- Potential unacceptable risk was identified for occupational and construction worker direct contact with soil containing benzo(a)pyrene. Estimated excess lifetime risks for these scenarios are:
  - Occupational Worker Exposure to benzo(a)pyrene – $9x10^{-6}$ to $3x10^{-5}$ for CT and RME, respectively; and
  - Construction Worker Exposure to benzo(a)pyrene – $3x10^{-6}$ for RME.

4.4 Hot Spot Evaluation

A Hot Spot may be present in soil if hazardous substances are present at unacceptable risk levels (OAR 340-122-0115(32)(b)) and, if present at high concentrations, are highly mobile, or cannot be reliably contained. Arsenic and benzo(a)pyrene were the only substances present at unacceptable risk levels. Arsenic and benzo(a)pyrene in soil are not highly mobile and can be reliably contained. Therefore, a Hot Spot would be present only if these COPC are present at high concentrations, defined (for carcinogenic compounds) as 100 times the concentration corresponding to the acceptable risk level. The occupational RBC for arsenic and benzo(a)pyrene in soil is 1.7 milligrams per kilogram (mg/kg) and 0.27 mg/kg, respectively. Therefore, the Hot Spot concentrations are 170 mg/kg and 27 mg/kg, respectively. The maximum detected concentrations of arsenic and benzo(a)pyrene were 18.7 mg/kg and 10.1 mg/kg, respectively. Therefore, there are no Hot Spots at OU4.

4.5 Uncertainty Evaluation

This section identifies assumptions and uncertainties inherent in the risk assessment in order to place the risk estimates in proper perspective. In general, the risk assessment was conducted in a manner such that the net result of assumptions made to address uncertainties was more likely to overestimate risk. For this risk assessment, the general sources of uncertainty addressed include:

- Data collection and evaluation;
- Exposure assessment;

- Toxicity assessment; and
- Risk characterization.

4.5.1 Data Collection and Evaluation

The identification of the types and numbers of environmental samples, sampling procedures, and sample analyses each contain components that contribute to uncertainties in this risk assessment. For example, it is generally not practical to sample all locations and media at a site. Decisions were made to select a subset of the potential sampling locations and media based upon the anticipated presence of the chemical. These decisions were made with the use of historical and background information on the Facility and the potential contaminants' chemical and physical properties. Exposure doses for the Facility that are based on non-random – or source area – samples may be overestimated.

4.5.2 Exposure Assessment

The exposure estimation methods are subject to varying degrees of uncertainty. The degree of uncertainty generally depends on the amount of Facility-specific data available. The following sources of uncertainty have been identified:

- Exposure Scenario Identification: This baseline HHRA assumes that receptors are limited to occupational, construction, and excavation workers. If these assumptions are incorrect, future risks and hazards could be under- or overestimated.
- Exposure Parameters and Assumptions: The exposure assumptions may or may not be representative of the actual exposure conditions and could under- or overestimate future risks and hazards.

4.5.3 Toxicity Assessment

Toxicity Factors. Uncertainty is present in the derivation of the toxicity factors used to derive the RBCs used in this baseline HHRA. Toxicity factors are derived primarily from animal studies. These necessarily require extrapolation to humans; extrapolation from high-dose to low-dose situations; and extrapolation from one exposure pathway to another (e.g., oral to dermal). In addition, the studies have difficulty accounting for population variability, and the quality of studies varies among chemicals. All of these factors may result in either an over- or underestimation of risk. These uncertainties are typically addressed with the use of uncertainty factors such that reference doses for non-carcinogens and slope factors for carcinogens result in upper-bound estimates of risk.

Uncertainty associated with determining chemical carcinogenicity is reflected in the weight-of-evidence classification groups assigned to carcinogens. In addition, uncertainties are introduced because slope factors are derived from the low-dose end of the dose-response curves, and the experimental studies are usually conducted at the high-dose end of the curve. The selected 95% UCL of the slope of the dose-response curve is considered an upper-bound toxicity value. Therefore, it is unlikely that the slope factors will underestimate risk. Actual cancer risk may range from a low of zero to the upper limit defined by the model.

Uncertainty is also associated with using oral toxicity factors to evaluate dermal exposures. The use of oral toxicity factors as surrogates is necessary because there are no dermal toxicity factors approved by EPA. Most of the uncertainty exists because it is unknown whether the compounds in question exhibit the same toxicity via dermal contact as they do via the oral pathway. Default oral absorption factors were used to adjust the oral toxicity factors so the absorbed doses calculated for the dermal pathway could be evaluated. The use of the oral absorption factors may bias the risk and hazard estimates high or low.

4.5.4 Risk Characterization

This baseline HHRA used EPA/DEQ standard algorithms to calculate health risks and hazards. There are certain assumptions inherent in the use of these equations that add uncertainty. For example, calculations of carcinogenic risks and non-carcinogenic HI assume that the toxic effects are additive. This assumption adds uncertainty to the assessment and may result in an overestimation or underestimation of the potential risks, depending on whether antagonistic or synergistic conditions apply. Exposure pathway risks are combined assuming that a single receptor may be concurrently exposed to contamination through a selected number of pathways. This is a conservative estimate that may overestimate risks and hazards. Additionally, the standard algorithms used do not consider certain factors, such as absorption or matrix effects. In cases where these processes are important, the risk estimates may overestimate or underestimate the potential human risks at this site.

4.6 Baseline HHRA Summary and Conclusions

The baseline HHRA for the Facility was completed in accordance with relevant guidance, and under the baseline conditions, the results of this baseline HHRA are summarized as follows:

- Potential unacceptable risk was identified for occupational worker direct contact with soil containing arsenic and benzo(a)pyrene. The arsenic risk resulted from the concentration detected in one soil sample (other samples were at background). The majority of the risk results from exposure to benzo(a)pyrene.
- Potential unacceptable risk was identified for construction worker direct contact with shallow soil containing benzo(a)pyrene.
- No Hot Spots were identified at OU4.

Because potential unacceptable risks were identified under a baseline scenario, an FS is warranted for OU4. Given that the potential unacceptable risk is limited to two COPC in a single medium (soil) and that the Facility is currently covered with an asphalt concrete parking lot, the FS may be streamlined.

5.0 Focused Feasibility Study

5.1 Remedial Action Objectives and Evaluation Criteria

5.1.1 Remedial Action Objectives

The DEQ provides applicable, current guidance regarding risk-based management of sites with contamination from petroleum and other constituents (DEQ, 2003; with 2009 updates). The guidance includes RBCs for the COPC for exposure pathways of interest. The remedial action objectives (RAOs) for the site will be to address the potential risk posed by benzo(a)pyrene and arsenic by mitigating exposure in the identified remedial action areas to achieve site-wide concentrations below the following RBCs:

- Benzo(a)pyrene
  - Occupational exposure RBC = 0.27 mg/kg
  - Construction exposure RBC = 2.1 mg/kg
- Arsenic
  - Occupational exposure RBC = 1.7 mg/kg

5.1.2 Evaluation Criteria

The evaluation of potentially feasible alternatives was based on the following criteria (OAR 340-122-085(4)).

5.1.2.1 Protectiveness

Protectiveness is a threshold requirement; only alternatives that meet the protectiveness requirements were evaluated (OAR 340-122-040). The protectiveness standards are:

- Ability of remedial action to protect present and future public health, safety, and welfare;
- Ability of remedial action to achieve acceptable risk levels specified in OAR 340-122-115;
- Ability of remedial action to prevent or minimize future releases and migration of hazardous substances in the environment; and
- Requirements for long-term monitoring, operation, maintenance, and review.

5.1.2.2 Balancing Factors

Balancing Factors include the following (OAR 340-122-090(3)):

- Effectiveness: Ability and timeframe of remedial action to achieve protection through eliminating or managing risk;
- Long-Term Reliability: Reliability of remedial action to eliminate or manage risk and associated uncertainties;
- Implementability: Ease or difficulty of implementing a remedial action considering technical, mechanical, and regulatory requirements;
- Implementation Risk: Potential impacts to workers, the community, and the environment during implementation; and
- Reasonableness of Costs: Considers capital costs, operations and maintenance, and periodic review, and includes a net present-value evaluation of the remedial action.

5.1.2.3 Treatment or Removal of Hot Spots

Hot Spots are evaluated based on the feasibility of treatment/removal of the Hot Spot using the above balancing factors with a higher threshold for cost reasonableness (OAR 340-122-085(5,6,7), -090(4)). The higher threshold is applied only as long as the Hot Spot exists. There were no Hot Spots identified applicable to this FS.

5.2 Remedial Action Area and Extent

Figure 8 shows the locations of soil samples with COPC above RAOs and defines the remedial action areas. The spatial characteristics of these areas are summarized as follows:

- Depth below ground surface: 0 feet
- Area: Arsenic area – 5,000 square feet
PAH area – 110,000 square feet
- Thickness: Arsenic area – assumed 3 feet
PAH area – varies from assumed 3 to estimated 20 feet
- Volume: Occupational RAO, 0 to 3 feet – 13,000 cubic yards
Occupational RAO, full depth – 37,000 cubic yards
- Mass: Occupational RAO, 0 to 3 feet – 21,000 tons
Occupational RAO, full depth – 60,000 tons

5.3 Remedial Action Alternatives and Preliminary Screening

Initially, remedial actions associated with a list of general response actions were screened for applicability based on Facility and soil conditions and contaminant type. General response actions are broad categories of remedial measures that address the RAOs. A response action may be a stand-alone remedial action alternative or a component of a comprehensive alternative. The list of general response actions includes:

- No Action;
- Institutional/Engineering Controls;
- Removal;
- Containment;
- *In Situ* Biological Treatment;
- *In Situ* Physical/Chemical/Thermal Treatment;
- *Ex Situ* Biological Treatment; and
- *Ex Situ* Physical/Chemical/Thermal Treatment.

Table 5 lists the general response actions together with representative remedial action technologies for soil. Based on Facility use and type and extent of contaminants, these remedial action technologies were screened to identify a list of technologies to include in a more detailed evaluation of potential remedial action alternatives. The results of the screening are shown in Table 5, with the shaded technologies eliminated from further consideration. Comments on the table explain the rationale for eliminating technologies from further consideration.

Remedial action technologies for soil that remained following the initial screening include:

- No Action;
- Access Control (fenced facility, soil management plan, deed restriction);
- Monitoring;
- Excavation;
- Off-Site Disposal; and
- Cap.

As appropriate, technologies are combined to form functional alternatives (such as combining excavation and off-site disposal). The No Action alternative is kept through the evaluation process to serve as a baseline for comparison. Therefore, the proposed alternatives (with corresponding technologies) for detailed analysis include the following:

- No Action;
- Cap (cap, access control, deed restriction, soil management plan, monitoring);
- Shallow Excavation and Disposal (excavation, off-site disposal, access control, deed restriction, soil management plan, monitoring); and
- Excavation and Disposal (excavation, off-site disposal, monitoring).

These alternatives are included in the evaluation of alternatives in Section 5.4.

5.4 Detailed Analysis of Remedial Action Alternatives

This section describes and evaluates each of the remedial action alternatives identified in Section 5.3. Feasibility of the alternatives was evaluated using the criteria in Section 5.1.2.

Following the evaluation, a comparative analysis of each alternative relative to every other alternative was completed (Section 5.5). The comparative analysis serves as the basis for selecting the recommended remedial action alternative (Section 5.6).

5.4.1 No Action

Description. According to OAR 340-122-085(2), a No Action alternative must be evaluated as a remedial action alternative. The No Action alternative assumes that no action is taken, no monitoring is performed, and no costs are incurred.

Protectiveness. The No Action alternative is not protective because it allows contaminants to be left in place at concentrations that exceed acceptable risk levels.

Effectiveness. The No Action alternative is not effective because it does not eliminate or manage risk.

Long-Term Reliability. The No Action alternative is not reliable because is will not effectively manage risk.

Implementability. The No Action alternative is the easiest of the alternatives to implement.

Implementation Risk. Since there are no construction or remediation activities associated with the No Action alternative, there is no risk to workers, environment, or the public during implementation of this alternative.

Reasonableness of Cost. There is no cost associated with the No Action alternative.

5.4.2 Cap

Description. For this alternative, the existing paved parking lot will be designated as a protective cap preventing direct contact with soil containing COPC above RAOs. Figure 9 shows the area of the soil cap at OU4. The capping of the soil includes the following components:

- The remedial action areas identified in Section 5.2 are currently covered with an asphalt concrete parking lot. The cap section is typically 4 inches of asphalt concrete overlying 5 inches of crushed rock base, but varies from 3 inches on 9 inches to 5 inches on 11 inches (asphalt concrete overlying crushed rock base). The parking lot cap will prevent direct contact by occupational workers.
- Long-term operation and maintenance of the cap would involve annual inspections and sealing observed cracks on an assumed schedule of every five years.
- Management of risks associated with future construction activities in these areas would be addressed with a soil management plan (SMP). The SMP would delineate remedial action areas, identify appropriate soil handling and protective measures for construction activities within the remedial action areas at the Facility, and identify maintenance/inspection requirements for capped areas.
- A deed restriction would be recorded to notify future owners of the presence of the cap, impacted soil, and SMP requirements.

Protectiveness. The cap alternative is protective by managing risk through the use of a cap and institutional controls. The cap will protect present and future risk to public health, safety, and welfare and prevent future migration. Long-term requirements are reasonable.

Effectiveness. The cap alternative is effective by preventing direct contact with the soil by occupational workers. Additionally, the institutional controls (access restriction and deed restriction) are effective immediately after implementation by limiting access to only authorized personnel and administratively eliminating direct contact with the impacted soil. An SMP will be incorporated into the alternative to address risks associated with future construction worker exposure in the remedial action areas and to address long-term maintenance/inspection of the cap. There are no long-term monitoring requirements. The cap has already been implemented. Preparation and implementation of the SMP can be implemented quickly and is effective immediately.

Long-Term Reliability. This alternative does not reduce the toxicity or mobility of the contaminants. However, toxicity reduction will occur through time by natural attenuation of benzo(a)pyrene. The long-term reliability of this alternative requires maintenance of the cap and enforcement of the SMP.

Implementability. This remedial action alternative is easy to implement because the cap is already in place. Development of the SMP is also easy. Ongoing implementation of the SMP requires continued enforcement and education.

Implementation Risk. Since there are no construction or remediation activities associated with the cap alternative (because the cap is already in place), there is no short-term risk to workers or the public.

Reasonableness of Cost. The present worth cost associated with the cap alternative is $25,000, including $10,000 capital cost (preparing the SMP) and $15,000 present worth cost for long-term inspection of the cap (annual inspections; assumes crack repair is a normal part of parking lot maintenance). Table 6 presents additional detail for the cost estimate.

5.4.3 Shallow Excavation and Disposal

Description. For this alternative, impacted soil within the upper 3 feet would be excavated and disposed of off the Facility. Remaining soil would be managed with institutional controls. Figure 10 shows the area of the shallow soil excavation. This alternative includes the following components:

- Shallow soil (0 to 3 feet in depth) would be excavated from the shallow soil remedial action area and transported to a local special waste landfill (21,000 tons);
- Clean imported fill would be used to replace soil excavated from the shallow soil remedial action area.
- Storm drain components (catch basins, piping) would be replaced as necessary.
- Base course (6 inches thick) and new asphalt concrete pavement (4 inches thick) would be placed to restore the parking lot.
- Management of risks associated with future construction activities in these areas would be addressed with an SMP. The SMP would delineate the location of remaining impacted soil and identify appropriate soil-handling and protective measures for construction activities within the remedial action areas at the Facility.
- A deed restriction would be recorded to notify future owners of the presence of the impacted soil and SMP requirements.

Protectiveness. This alternative achieves protection by removing contaminated soil to a controlled facility and addressing potential future construction worker risk with an SMP.

Effectiveness. Landfill disposal is effective at preventing contact by removing the contaminated soil to a controlled facility. An SMP would be incorporated into the alternative to address risks associated with construction worker exposure during future construction. The alternative is protective immediately after implementation (expected to take two to three months to complete).

Long-Term Reliability. Disposing of the soil at a landfill would eliminate the human health risk from the soil by removing the contaminant source to a managed facility. Landfill disposal does not reduce the toxicity or mobility of the contaminants. This alternative otherwise has good long-term reliability because the landfill is a controlled disposal facility that is required to conduct long-term maintenance and monitoring. The long-term reliability of this alternative partially depends on enforcement of the SMP for future construction projects.

Implementability. This remedial action alternative is moderately difficult to implement because the excavation would be completed within an active parking area with limited alternative parking areas. Development of the SMP is easy. Ongoing implementation of the SMP requires continued enforcement and education.

Implementation Risk. Risks that may be realized during implementation of this alternative include exposure to construction workers during the soil excavation (which can be managed through engineering controls and worker protection) and the potential for spilling of soil during transport to the landfill area. Trucks would be covered to prevent material spilling.

Reasonableness of Cost. The estimated total cost of this remedial action alternative is $1,950,000. There are no long-term costs. Table 6 presents additional detail for the cost estimate.

5.4.4 Excavation and Disposal

Description. For this alternative, impacted soil would be excavated and disposed of off the site. Figure 10 shows the area of the soil excavation. This alternative includes the following components:

- Soil impacted above occupational RAOs (estimated to be in the range of 0 to 20 feet in depth) would be excavated from the remedial action area and transported to a local special waste landfill (60,000 tons);
- Clean imported fill would be used to replace soil excavated from the remedial action area.
- Storm drain components (catch basins, piping) would be replaced as necessary.
- Base course (6 inches thick) and new asphalt concrete pavement (4 inches thick) would be placed to restore the parking lot.

Protectiveness. This alternative achieves protection by removing the contaminated soil to a controlled facility.

Effectiveness. Landfill disposal is effective at preventing direct contact by removing the contaminated soil to a controlled facility. The alternative is protective immediately after implementation (expected to take two to three months to complete).

Long-Term Reliability. Disposing of the soil at a landfill would eliminate the human health risk from the soil by removing the contaminant source to a managed facility. Landfill disposal does not reduce the toxicity or mobility of the contaminants. This alternative otherwise has good long-term reliability because the landfill is a controlled disposal facility that is required to conduct long-term maintenance and monitoring.

Implementability. This remedial action alternative is moderately difficult to implement because the excavation would be completed within an active parking area with limited alternative parking areas.

Implementation Risk. Risks that may be realized during implementation of this alternative include exposure to construction workers during the soil excavation (which can be managed through engineering controls and worker protection) and the potential for spilling of soil during transport to the landfill area. Trucks would be covered to prevent material spilling.

Reasonableness of Cost. The estimated total cost of this remedial action alternative is $4,820,000. There are no long-term costs. Table 6 presents additional detail for the cost estimate.

5.5 Comparative Evaluation of Remedial Action Alternatives

This section of the FS presents an evaluation of the remedial action alternatives relative to one another. The comparative analysis is summarized in Table 7. In the table, each alternative is compared to each of the other alternatives for each evaluation criterion. An alternative is ranked as favorable (+), equal (0), or unfavorable (-) in relation to every other alternative. The scores are summed at the right of the table for each alternative and then ranked. The following discussion provides a rational for the comparative evaluation presented in Table 7.

5.5.1 Protectiveness

This criterion is pass/fail. An alternative must be protective as defined by OAR 340-122-040 to be acceptable. With the exception of the No Action alternative, each of the remedial action alternatives is protective of human health. The alternatives were not scored based on this criterion, but protectiveness was considered when ranking the alternatives in the right-hand column.

5.5.2 Effectiveness

The alternatives were ranked based on effectiveness of the alternative and the time required to complete the remedial action. Each of the alternatives would be effective within a few months so no distinction was made based on timeframe. The excavation alternative was considered to be the most reliable because the soil above RAOs is removed to a controlled facility. The shallow excavation alternative was considered to be more reliable than the cap alternative because some of the soil is removed to a controlled facility. The no action alternative was not considered to be an effective remedial alternative.

5.5.3 Long-Term Reliability

Alternatives that permanently treat (or dispose of) the contamination ranked the highest. Therefore, the excavation alternative ranked highest. The shallow excavation alternative is considered more permanent and reliable than the cap alternative in the long-term because some of the soil above RAOs is removed to a controlled facility. The no action alternative was not considered to be a reliable remedial alternative.

5.5.4 Implementability

The no action alternative was considered the most easily implemented remedial action. The cap alternative ranked next because no site construction activities would be required. The excavation alternatives both will have significant impact on the usability of the parking lot during construction. The excavation alternative was considered to be slightly more implementable than the shallow excavation alternative because it does not require long-term implementation of the SMP.

5.5.5 Implementation Risk

The no action and cap alternatives carry no implementation risk. Both excavation alternatives have risk associated with potential worker exposure and transport of soil on highways (both risks are managed with planning and implementation of best management practices). The shallow excavation alternative ranks higher because of the lesser quantity of soil to be excavated.

5.5.6 Reasonableness of Cost

Cost estimates were developed for each of the remedial alternatives based on capital and long-term costs. The following list summarizes the present-worth total cost estimates for each alternative:

- No Action ($0);
- Cap ($25,000);
- Shallow Excavation and Disposal ($1,950,000); and
- Excavation and Disposal ($4,820,000).

5.6 Recommendation

5.6.1 Recommended Remedial Action Alternative

Based on the evaluation of remedial action alternatives, the highest ranking protective alternative is the cap alternative. This alternative is recommended as being protective (by preventing direct contact with soil by occupational workers and controlling risks under the administration of an SMP for future construction workers) and having the best overall ranking. It is easy to implement, has no implementation risk, and is the most cost-effective of the protective alternatives.

5.6.2 Residual Risk Assessment

As part of this evaluation, in accordance with OAR 340-122-084(4), a Residual Risk Assessment was completed for the recommended remedial action alternative. The Residual Risk Assessment included a quantitative assessment of risk resulting from unmanaged residuals at the Facility and a calculation of the managed risk. In this case, the residual risk is the potential risk for workers posed by soil COPC outside of the capped area, and the managed risk is the potential risk associated with worker exposure exclusively to the capped area.

Consistent with the HHRA (Section 4), the RME values for exposure parameters relating to occupational employees and excavation/construction workers were used in these calculations. For individual chemicals, Oregon DEQ generally considers excess cancer risks below $1x10^{-6}$ to be acceptable; for additive risks from multiple chemicals, DEQ considers risks less than $1x10^{-5}$ to be acceptable (OAR 340-122-115(2)(a), (3)(a)). The results of the Residual Risk Assessment are summarized in Table 8.

Implementation of the selected remedial action alternative (cap with an SMP) for the remedial action areas would result in the following residual risk estimates.

		Baseline Risk	Managed Risk	Residual Risk
Occupational Worker	CT	1×10^{-5}	3×10^{-5}	6×10^{-8}
	RME	3×10^{-5}	6×10^{-5}	1×10^{-7}
Construction Worker	CT	2×10^{-6}	3×10^{-6}	8×10^{-9}
	RME	4×10^{-6}	7×10^{-6}	1×10^{-8}

The Residual Risk Assessment concludes that the implementation of the cap alternative would effectively reduce risk to acceptable levels.

6.0 Source Control Evaluation

6.1 Potential Sources and Chemicals of Interest

6.1.1 Potential Contaminant Sources

The historical research conducted for the RI/FS Work Plan and supplemental PA identified past activities and features that may be areas of concern as contaminant sources on OU4. These are summarized in Section 2.2 and shown on Figure 3. Specifically, potential contaminant sources include:

- Historical airport runway;
- Military-era electrical substations A and R;
- General light industrial use of OU4.

Historical potential contaminant sources and historical storm water pathways to the river were investigated as summarized in Section 2.5.

6.1.2 Chemicals of Interest

For the SCE, COI were identified considering both nearshore sediment data and upland potential sources. Nearshore sediment data are screened to identify COI. Upland data are reviewed and chemicals detected in soil or groundwater are retained as COI.

Nearshore Sediment Data Screening. Constituents present in river sediments near the Facility at "elevated" concentrations were retained as COI. Cleanup levels for in-water sediment have not yet been developed. Therefore, JSCS soil/storm water sediment screening level values (SLVs) were used as a means to identify constituents that are elevated and only for the purpose of selecting COI. Tables D-1 through D-6 in Appendix D list the nearshore sediment data together with the JSCS screening levels. Concentrations above the SLVs are shaded in the tables. No PAHs or phthalates were detected at concentrations exceeding their SLVs. TPH was detected in surface sediments but there are no SLVs for TPH. Chemicals detected in sediments above SLVs and retained as COI for the SCE are summarized as follows:

- The total PCB concentration exceeded the JSCS bioaccumulation SLV of 0.39 micrograms per kilogram (µg/kg) at 6 of 8 locations (none of the individual Aroclors were detected above respective SLVs).
- The TBT concentration exceeded the JSCS SLV of 2.3 µg/kg at 2 of the 2 locations.

Soil, Groundwater, and Storm Water Solids Data. Based on potential sources summarized in Section 6.1, COI for upland investigations included metals, TPH, VOCs, PCBs, PAHs, phthalates, SVOCs, and butyltins. The investigations described in Section 2.5 included analyses for each of these COI, summarized as follows:

- Soil: Upland soils were analyzed for metals, TPH, VOCs, PCBs, PAHs, phthalates, SVOCs, and butyltins. VOCs, PCBs, phthalates, SVOCs (except PAHs), and TBT were not detected. Metals, TPH, PAHs, dibutyltin, and butyltin were detected in soil and are retained as COI.
- Groundwater: Groundwater samples collected on OU4 were analyzed for metals, TPH, VOCs, PCBs, PAHs, phthalates, SVOCs, and butyltins. Except for metals and PAHs, none of these compounds were detected in groundwater. Metals and PAHs are retained as COI in groundwater.
- Storm Water Solids: A sample collected from catch basin solids leading to outfall WR-399 was analyzed for metals, TPH, phthalates, TBT, PCBs, and PAHs. Each of these was detected and is retained as COI.
- Storm Water: A storm water sample collected from outfall WR-399 was analyzed for metals, TPH, phthalates, TBT, PCBs, and PAHs. Metals, TPH, phthalates, and PAHs were detected and are retained as COI.

Summary of Chemicals of Interest. Based on a review of nearshore sediment, soil, groundwater, storm water, and storm water solids data, COI identified for this SCE are:

- Metals;
- TPH;
- PCBs;
- PAHs;
- Phthalates; and
- Butyltins.

6.2 Upland Data Screening

6.2.1 Identification of Migration Pathways

In accordance with the JSCS guidance, the approach to the SCE includes the identification of each known or potentially complete migration pathway to the river. Potential migration pathways are evaluated in this section and include over water activities, storm water, storm water conveyances as a preferential groundwater migration pathway, riverbank erosion, and groundwater migration to the Willamette River. Potentially complete migration pathways are further evaluated in Section 6.3.

- Over Water Activities – There were/are no over water activities at OU4, so this pathway is not further evaluated.

- Storm Water Pathway – OU4 is a paved parking lot with multiple catch basins that discharge to outfall WR-399. In 2008, as part of the sale of the OU4 parking lot to Shipyard Commerce Center LLC, the Port cleaned the storm water system. As a further part of the sale, the Port and Shipyard Commerce Center LLC agreed that Vigor (operator of the shipyard) would assume responsibility for completing any further storm water system evaluation and storm water remedial action. Therefore, this pathway is not further assessed.
- Storm Water Conveyances as Preferential Groundwater Migration Pathway – This pathway is incomplete. As discussed in Section 2, the depth to groundwater ranges from 18 to 30 feet bgs at the SIUF. This range of variation is based on six years of water level monitoring at SIUF monitoring wells over a broad range of Willamette River elevations. Active and inactive storm water pipes are or were located at shallower depths (i.e., above the seasonal high water table). Active outfall WR-399 is located approximately 5 to 10 feet below the top of the riverbank, above the water table (Ash Creek, 2008a). Therefore, this pathway is not further assessed.
- Riverbank Erosion Pathway – OU4 is not adjacent to the river and has no riverbank. Therefore, this pathway is not further assessed.
- Groundwater Pathway – Groundwater monitoring performed as part of the SIUF RI determined that groundwater beneath Swan Island flows either to the Willamette River or to Swan Island Lagoon. As OU4 is located on the south side of Swan Island, nearer the Willamette River, the direction of groundwater flow is expected to be to the southwest toward the river. Constituents present in groundwater and constituents that leach through soil to groundwater, therefore, have the potential to migrate to the river. This pathway is carried forward for further evaluation.

6.2.2 Data Screening

The groundwater pathway was identified as the only potentially complete pathway of concern. Groundwater data are screened in this section for the COI identified in Section 6.1.2

6.2.2.1 Initial Data Screening

Groundwater data collected on OU4 are presented in Table A-8 in Appendix A.

Metals. Arsenic, chromium, copper, lead, nickel, and zinc were detected in groundwater above the JSCS SLVs. Metals are further discussed in Section 6.2.2.2.

TPH. TPH was not detected in groundwater samples collected on OU4. Detection limits were 80 micrograms per liter (µg/L) for gasoline-range TPH, 240 µg/L for diesel-range TPH, and 500 µg/L for oil-range TPH. Therefore, TPH is not a COPC in groundwater and is not further evaluated.

PCBs. PCBs were not detected in groundwater samples collected on OU4. The detection limit was 1 µg/L for each Aroclor. Therefore, PCBs are not COPC in groundwater and are not further evaluated.

PAHs. Up to nine PAHs were detected above JSCS SLVs in 4 of 11 groundwater samples collected at OU4. PAHs are further evaluated in Section 6.2.2.3.

Phthalates. Phthalates were not detected in groundwater samples collected on OU4. The detection limit was 5 µg/L for each phthalate. Therefore, phthalates are not COPC in groundwater and are not further evaluated.

Butyltins. Butyltins were not detected in groundwater samples collected on OU4. Detection limits were 0.19 µg/L for TBT, 0.29 µg/L for dibutyltin, and 0.2 µg/L for butyltin. Therefore, butyltins are not COPC in groundwater and are not further evaluated.

6.2.2.2 Metals in Groundwater

Arsenic. Total arsenic was detected above the JSCS SLV of 0.045 µg/L in 11 of 11 samples analyzed, at concentrations ranging from 3.7 to 34 µg/L. This corresponds to SLV exceedances of 83 to 750 times. In the four samples collected nearest the river (GP-02, GP-03, GP-07, and GP-11), the SLV exceedances ranged from 140 to 450 times.

Chromium. Total chromium was detected above the JSCS SLV of 100 µg/L in 2 of 11 samples analyzed, at concentrations ranging from 101 to 221 µg/L. This corresponds to SLV exceedances of up to 2.2 times. None of the four samples collected from nearest the river exceeded the SLV.

Copper. Total copper was detected above the JSCS SLV of 2.7 µg/L in 11 of 11 samples analyzed, at concentrations ranging from 26 to 300 µg/L. This corresponds to SLV exceedances of 10 to 110 times. In the four samples collected nearest the river, the SLV exceedances ranged from 10 to 20 times.

Lead. Total lead was detected above the JSCS SLV of 0.54 µg/L in 11 of 11 samples analyzed, at concentrations ranging from 3.7 to 22 µg/L. This corresponds to SLV exceedances of 7 to 41 times. In the four samples collected nearest the river, the SLV exceedances ranged from 9 to 15 times.

Nickel. Total nickel was detected above the JSCS SLV of 16 µg/L in 11 of 11 samples analyzed, at concentrations ranging from 34 to 170 µg/L. This corresponds to SLV exceedances of 2 to 10 times. In the four samples collected nearest the river, the SLV exceedances ranged from 2 to 4 times.

Zinc. Total zinc was detected above the JSCS SLV of 36 µg/L in 11 of 11 samples analyzed, at concentrations ranging from 49 to 3,730 µg/L. This corresponds to SLV exceedances of 1.4 to 100 times. In the four samples collected nearest the river, the SLV exceedances ranged from 2 to 4 times.

6.2.2.3 PAHs in Groundwater

Up to nine PAHs were detected in 4 of 11 samples from OU4. Individual PAH concentrations ranged from 0.038 µg/L to 0.52 µg/L. SLV exceedance ratios ranged from approximately 20 to 100 for carcinogenic PAHs and from 1 to 3 for non-carcinogenic PAHs. In the four samples collected nearest the river (GP-02, GP-03, GP-07, and GP-11), PAHs were below the detection limit except for one PAH (naphthalene) detected in one sample (GP-02) below the SLV.

6.2.2.4 Leaching to Groundwater

Potential for leaching to groundwater was assessed by screening soil data against background and SLVs. COI concentrations in upland soil samples collected on OU4 are presented together with background concentrations (where applicable) and JSCS SLVs in Tables A-1 through A-7 in Appendix A. Figure 6 illustrates the upland soil sampling locations. COI detected in upland soil above background or SLVs are arsenic, copper, lead, nickel, mercury, zinc, and PAHs, summarized as follows:

- Arsenic was detected above background in 1 of 48 samples at a concentration of 19 mg/kg compared to the background concentration of 7 mg/kg, an exceedance of 2.7 times.
- Copper was detected above background in 2 of 44 samples at concentrations of 52 and 76 mg/kg compared to the background concentration of 36 mg/kg, an exceedance of 1.4 to 2.1 times.
- Lead was detected above background in 2 of 48 samples at concentrations of 28 and 49 mg/kg compared to the background concentration of 17 mg/kg, an exceedance of 1.7 to 2.9 times.
- Nickel was detected above background in 1 of 44 samples at a concentration of 43 mg/kg compared to the background concentration of 38 mg/kg, an exceedance of 1.1 times.
- Mercury was detected above background in 8 of 44 samples at concentrations of 0.094 to 1.83 mg/kg compared to the background concentration of 0.07 mg/kg, an exceedance of 1.3 to 26 times.
- Zinc was detected above background in 2 of 44 samples at concentrations of 88 and 101 mg/kg compared to the background concentration of 86 mg/kg, an exceedance of up to 1.2 times.
- PAHs were detected above the JSCS SLV in 6 of 44 samples. The six samples with PAHs above the SLVs correspond to soil within the upper 5 to 8 feet at three locations (GP-01/OU4-1, GP-04/OU4-2, and GP-06/OU4-5). These locations are within the interior of OU4 and correlate with where PAHs were detected above SLVs in groundwater. At the four locations nearest the river (GP-02, GP-03/OU4-3, GP-07/OU4-6, and GP-11/OU4-8), PAHs are mostly not detected in soil and are below SLVs in both soil and groundwater.

6.2.2.5 Groundwater Pathway Screening Summary

Groundwater sample results indicated that metals and PAHs were present in groundwater above SLVs. Soil sample results screened to assess potential for leaching to groundwater showed that several metals were detected above background soil concentrations, and PAHs were detected in soil at three interior locations. At the four sample locations nearest the river, COI were not detected above SLVs in soil, and only several metals were detected in groundwater above screening levels.

6.3 Groundwater Source Control Evaluation

This section presents a detailed evaluation of potential sources to the Willamette River from OU4. For each potentially complete pathway to the river as defined in Section 6.2.1 (groundwater pathway only), COI were screened in Section 6.2.2. For the COPC (COI detected above screening levels), a weight-of-evidence evaluation is presented below based on applicable site-specific factors listed in Sections 5.1.2 and 5.3 of the JSCS guidance.

Groundwater and soil data were screened in Section 6.2.2 to assess direct groundwater discharge to the river and leaching to groundwater pathways. In general, there is a lack of correlation between COPC in groundwater (primarily arsenic, copper, zinc, and PAHs based on exceedances of SLVs by factors of 70 to 700) and elevated chemicals in nearby sediments (total PCBs and TBT). Based on the data screening, the lack of correlation between COPC in groundwater and sediments, and the weight-of-evidence evaluation below, the groundwater pathway from OU4 is insignificant for contaminant loading to the Willamette River.

The screening of the groundwater samples identified metals and PAHs above JSCS groundwater/surface water/storm water SLVs. The following summarizes the frequency and magnitude of SLV exceedances for groundwater at OU4.

Constituent	Frequency of SLV Exceedance	Magnitude of SLV Exceedance	Magnitude of SLV Exceedance in Samples Nearest River
Arsenic	11/11	83 – 750	140 – 450
Chromium	2/11	1 – 2	<1
Copper	11/11	10 – 110	10 – 20
Lead	11/11	7 – 41	9 – 15
Nickel	11/11	2 – 10	2 – 4
Zinc	11/11	2 - 100	2 – 4
Benzo(a)anthracene	3/11	28 – 58	nd
Benzo(a)pyrene	4/11	21 – 78	nd
Benzo(b+k)fluoranthene	3/11	6 – 11	nd

Constituent	Frequency of SLV Exceedance	Magnitude of SLV Exceedance	Magnitude of SLV Exceedance in Samples Nearest River
Chrysene	3/11	34 – 86	nd
Fluoranthene	2/11	1 – 2	nd
Indeno(1,2,3-cd)pyrene	3/11	30 – 71	nd
Phenanthrene	2/11	1 – 2	nd
Pyrene	2/11	2 – 3	nd

Note: nd = not detected

Arsenic. The arsenic concentrations detected in groundwater on OU4 represent background concentrations based on the following.

- Arsenic in soil on OU4 is within the background range of arsenic for 47 of 48 soil samples and the one sample above background exceeded by less than three times.
- Detected concentrations of arsenic in groundwater are within the range of natural concentrations of arsenic in groundwater within the Willamette Basin. A report prepared by the United States Geological Survey (Hinkle and Polette, 1999) found concentrations of arsenic within the Willamette Basin to range from <1 to 2,000 µg/L with 22 percent of the samples greater than 10 µg/L. The detected concentrations of arsenic at OU4 ranged from 3.7 to 34 µg/L.
- The range of detected concentrations of arsenic in groundwater at OU4 is consistent with concentrations detected at other waterfront sites. For example, the following compares the ranges of detected concentrations of arsenic at OU4 with Terminal 4 Slip 1 (T4S1) and SIUF OU2.

Data Set	Concentration Range in µg/L		
	SIUF OU4	SIUF OU2	T4S1
Grab GW, Total As	3.7 - 34	3.8 - 39	<0.5 - 36

Chromium. Based on the low frequency and magnitude of SLV exceedances, and the concentrations detected in samples nearest the river that are below the SLV, chromium does not represent a significant contaminant loading from OU4 to the river via the groundwater pathway.

Other Metals. Based on the following, copper, lead, nickel, and zinc do not represent a significant contaminant loading from OU4 to the river via the groundwater pathway.

- Exceedances in samples nearest the river are lower than samples collected in the center of OU4. Maximum exceedances nearer the river range from 4 to 40 percent of those farther from the river.

- Groundwater data for OU4 consist of results from grab groundwater samples from borings. This sampling method typically results in relatively higher suspended solids present in the samples (compared to samples collected from monitoring wells) because of the disturbance associated with the sample collection. Consequently, total metals analysis from grab groundwater samples tend to be biased high compared to groundwater concentrations in samples collected from monitoring wells. This result is demonstrated by the groundwater data collected at the SIUF. Table E-1 in Appendix E compares groundwater metals data from monitoring wells and grab groundwater samples collected at the SIUF. For each monitoring well, the concentration detected in an immediately adjacent grab groundwater sample is compared to the mean concentration detected in the well (expressed as the ratio of the well concentration to the grab sample concentration). For each of copper, lead, nickel, and zinc, only 1 of the 11 locations had ratios exceeding one (corresponding to the well concentration greater than the grab groundwater concentration). For the one exceedance, well MW-5, the detected concentrations in both the well and grab samples were near or less than the SLV. For the remaining 10 locations, the ratios ranged from 0.01 to 0.37 with median values for copper, lead, nickel, and zinc of 0.06, 0.06, 0.1, and 0.02, respectively. These ratios were used with the detected grab groundwater concentrations to estimate hypothetical monitoring well concentrations at each location at OU4. These hypothetical concentrations were compared to the SLVs as summarized below. These results predict relatively low exceedances of SLVs, and concentrations at locations nearest the river are predicted to be at or below the SLVs.

Constituent	Frequency of SLV Exceedance in Hypothetical Wells	Magnitude of SLV Exceedance in Hypothetical Wells	Magnitude of SLV Exceedance in Hypothetical Wells Nearest River
Copper	6/11	1 – 7	1
Lead	5/11	1 – 2	<1
Nickel	1/11	1	<1
Zinc	1/11	2	<1

PAHs. Based on the following, PAHs do not represent a significant contaminant loading from OU4 to the river via the groundwater pathway:

- Individual PAH compounds were detected in only two to four out of 11 samples collected.
- Table E-2 in Appendix E compares groundwater PAH data from monitoring wells and grab groundwater samples collected at the SIUF in a similar fashion as for metals in Table E-1. For many of the sample events, there are a large number of non-detect values so the data for PAHs are less definitive than for metals. Furthermore, unlike metals, PAHs are not a natural component of soils so will tend to correlate less well to turbidity levels. However, the data in Table E-2 show the following tendencies. Low molecular weight PAHs such as naphthalene have ratios between monitoring well and grab sample results near one. For higher molecular weights, the median ratio

is on the order of 10 to 30 percent. These results suggest that the SLV exceedance ratios for PAHs in groundwater are more likely in the range of 2 to less than 20.

- PAHs were detected above SLVs only in interior samples. Samples collected from the four locations nearest the river were below detection limits except for naphthalene in one sample was detected at less than half the SLV.

Potential Leaching from Soil. In Section 6.2.2.4, soil data were screened to assess the potential for leaching of chemicals present in soil. Based on that screening, potential contaminant loading originating from leaching of chemicals from soil is not significant. Only metals and PAHs were detected in soil above background or SLVs. Except for mercury, metals were detected in soil above background in only one or two samples, and the detected concentrations exceeded background by less than three times. Mercury was detected above background in 8 of 44 samples. The mercury data were statistically evaluated using EPA's ProUCL software. The 95% UCL of the mean concentration was estimated to be 0.19 mg/kg, less than three times the background concentration of 0.07 mg/kg. Furthermore, mercury was detected in only 2 of 11 groundwater samples at concentrations of 0.112 and 0.212 µg/L, compared to the detection limit of 0.1 µg/L, supporting that mercury is not leaching from soil at unacceptable concentrations. PAHs were detected above SLVs in soil in the interior of OU4. PAHs were detected in groundwater in the same locations. However, the sample locations between the OU4 interior and the river demonstrate that the PAHs are localized and not migrating to the river: except for naphthalene in one sample, PAHs were not detected in the groundwater samples nearer to the river.

6.4 Source Control Evaluation Findings and Conclusions

Existing and potential sources to the Willamette River at OU4 were identified and characterized. Upland soil and groundwater sampling were performed at the SIUF under a DEQ-approved RI/FS Work Plan that was based on a detailed evaluation of historical activities and operations conducted at the SIUF and later supported by the supplemental PA. Additional soil and groundwater sampling was conducted during due diligence evaluations associated with sale of the property and at the request of the DEQ. Samples of storm water and storm water solids were collected from the OU4 storm water system.

Groundwater was identified as the only potential pathway to be evaluated for contaminant transport to the Willamette River (potential sources to the river via the storm water pathway will be evaluated by the current property owner). The groundwater pathway was evaluated and constituent migration via groundwater discharge is not a pathway of concern based on the following:

- Groundwater samples were analyzed for metals, TPH, VOCs, PCBs, PAHs, phthalates, SVOCs, and butyltins and only metals and PAHs were detected in groundwater.
- Analyses for metals were conducted on grab samples that typically result in detected concentrations that are biased high. Using data from the SIUF, these data were adjusted to

represent likely concentrations from hypothetical wells on the Facility. Resulting concentrations were consistent with background and/or at or below SLVs.

- PAHs were detected above SLVs only in interior groundwater samples. Samples collected from the four locations nearest the river were below detection limits except for naphthalene was detected in one sample at less than half the SLV.
- COPC detected in groundwater do not correlate with chemicals detected at elevated concentrations in nearby river sediments.

Based on the data evaluation and consideration of other lines of evidence, the potential contaminant migration pathways to the river at OU4 are incomplete or not of concern. No implementation of source control measures is recommended for OU4.

7.0 Conclusions

Soil, groundwater, and storm water data were used together with remedial investigation results for the SIUF to complete a risk assessment, FS, and SCE to support a no further action determination for OU4 at the SIUF. In summary, these studies concluded the following:

- The Level I Scoping Ecological Risk Assessment recommended that no further action is required for the OU4 area.
- The baseline HHRA for the Facility concluded the following:
  - Potential unacceptable risk was identified for occupational worker direct contact with soil containing arsenic and benzo(a)pyrene. The arsenic risk resulted from the concentration detected in one soil sample (other samples were at background). The majority of the risk results from exposure to benzo(a)pyrene.
  - Potential unacceptable risk was identified for construction worker direct contact with shallow soil containing benzo(a)pyrene.
  - No Hot Spots were identified at OU4.
- An FS was completed for OU4 to recommend a remedial action to address unacceptable baseline risk. The recommended remedial action for the Facility is summarized as follows:
  - Utilize the existing asphalt concrete parking lot as a cap to address potential risk to occupational workers.
  - Prepare and implement an SMP to address potential future construction worker risk and to specify considerations for soil handling and future site development.
  - Implement a deed restriction identifying the presence of the remedial action area and the need to implement the SMP.

- The SCE concluded that the potential contaminant migration pathways to the river at OU4 are incomplete or not of concern and that no implementation of source control measures is recommended for OU4.

Upon preparation of the SMP and the deed restriction, no further action will be required at OU4.

8.0 References

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Table 1
Soil Human Health Chemicals of Potential Concern
Swan Island Upland Facility - OU4

Chemicals of Interest	Soil (see units below)												Chemicals of Potential Concern [4]
	Detection Frequency				Detection Limit Range		COPC Screening						
	Det.	/	Total	%	Min.	Max.	SL	Cij	Rij	COPC?	Rij/Rj	COPC?	
Total Petroleum Hydrocarbons							mg/kg						
Gasoline-Range Organics	0	/	44	0%	3.8	27	2.2E+04	--	--	No	--	No	
Diesel-Range Organics	3	/	52	6%	22	68	7.0E+04	1.9E+02	2.7E-03	No	4.7E-05	No	
Residual-Range Organics	6	/	56	11%	44	140	7.0E+04	5.4E+02	7.7E-03	No	1.3E-04	No	
Metals							mg/kg						
Antimony	0	/	44	0%	0.5	1.52	4.1E+02	--	--	No	--	No	
Arsenic[3]	46	/	48	96%	1.29	1.43	5.8E+00	1.9E+01	1.1E+01	Yes	1.9E-01	Yes	Arsenic
Barium	4	/	4	100%	--	--	1.0E+05	1.6E+02	1.6E-03	No	2.7E-05	No	
Beryllium	0	/	36	0%	2.14	3.03	2.0E+03	--	--	No	--	No	
Cadmium	0	/	44	0%	0.079	1.52	5.0E+02	--	--	No	--	No	
Chromium (total)[5]	48	/	48	100%	--	--	1.9E+02	3.5E+01	1.8E-01	No	3.2E-03	No	
Copper	44	/	44	100%	--	--	1.2E+04	7.6E+01	6.4E-03	No	1.1E-04	No	
Lead	46	/	48	96%	5	5	8.0E+02	4.9E+01	6.1E-02	No	1.0E-03	No	
Mercury	12	/	44	27%	0.086	0.14	9.3E+01	1.8E+00	2.0E-02	No	3.4E-04	No	
Nickel	44	/	44	100%	--	--	6.1E+03	4.3E+01	7.1E-03	No	1.2E-04	No	
Selenium	0	/	36	0%	5.35	7.58	5.1E+03	--	--	No	--	No	
Silver	0	/	44	0%	0.5	3.03	1.5E+03	--	--	No	--	No	
Thallium	0	/	36	0%	1.09	1.52	--	--	--	No	--	No	
Zinc	44	/	44	100%	--	--	3.1E+05	1.0E+02	3.3E-04	No	5.6E-06	No	
PCBs							µg/kg						
Aroclor 1016	0	/	44	0%	9.6	33	9.8E+02	--	--	No	--	No	
Aroclor 1221	0	/	44	0%	20	33	9.8E+02	--	--	No	--	No	
Aroclor 1232	0	/	44	0%	9.6	33	9.8E+02	--	--	No	--	No	
Aroclor 1242	0	/	44	0%	9.6	33	9.8E+02	--	--	No	--	No	
Aroclor 1248	0	/	44	0%	9.6	33	9.8E+02	--	--	No	--	No	
Aroclor 1254	0	/	44	0%	9.6	33	9.8E+02	--	--	No	--	No	
Aroclor 1260	0	/	44	0%	9.6	33	9.8E+02	--	--	No	--	No	
Total PCBs	0	/	44	0%	--	--	9.8E+02	--	--	No	--	No	
PAHs							µg/kg						
Naphthalene	6	/	44	14%	8.5	938	2.3E+04	1.3E+02	5.8E-03	No	1.0E-04	No	
1-Methylnaphthalene	0	/	8	0%	8.5	45	9.9E+04	--	--	No	--	No	
2-Methylnaphthalene	2	/	8	25%	8.5	45	4.1E+06	5.2E+01	1.3E-05	No	2.2E-07	No	
Acenaphthylene[1]	3	/	44	7%	8.5	938	4.1E+06	1.2E+03	2.8E-04	No	4.8E-06	No	
Acenaphthene	1	/	44	2%	8.5	938	1.9E+07	6.8E+01	3.6E-06	No	6.2E-08	No	
Fluorene	3	/	44	7%	8.5	938	1.2E+07	2.8E+02	2.3E-05	No	4.0E-07	No	
Phenanthrene[1]	11	/	44	25%	8.5	938	4.1E+06	9.6E+03	2.3E-03	No	4.0E-05	No	
Anthracene	4	/	44	9%	8.5	938	9.3E+07	7.2E+02	7.7E-06	No	1.3E-07	No	
Fluoranthene	13	/	44	30%	--	938	8.9E+06	2.2E+04	2.4E-03	No	4.2E-05	No	
Pyrene	14	/	44	32%	--	938	6.7E+06	2.7E+04	4.0E-03	No	6.9E-05	No	
Benzo(a)anthracene	10	/	43	23%	8.5	938	2.7E+03	6.5E+03	2.4E+00	Yes	4.2E-02	Yes	Benzo(a)anthracene
Chrysene	10	/	44	23%	8.5	938	2.7E+05	8.8E+03	3.2E-02	No	5.6E-04	No	
Benzo(b)fluoranthene	10	/	44	23%	8.5	938	2.7E+03	8.3E+03	3.1E+00	Yes	5.3E-02	Yes	Benzo(b)fluoranthene
Benzo(k)fluoranthene	10	/	44	23%	8.5	938	2.7E+04	7.4E+03	2.7E-01	No	4.7E-03	No	
Benzo(a)pyrene	11	/	44	25%	8.5	1030	2.7E+02	1.0E+04	3.7E+01	Yes	6.5E-01	Yes	Benzo(a)pyrene
Indeno(1, 2, 3-cd)pyrene	8	/	44	18%	8.5	1030	2.7E+03	8.1E+03	3.0E+00	Yes	5.2E-02	Yes	Indeno(1, 2, 3-cd)pyrene
Dibenz(a,h)anthracene	0	/	44	0%	8.5	1030	2.7E+02	--	--	No	--	No	
Benzo(g, h, i)perylene[2]	10	/	44	23%	8.5	1030	2.7E+04	1.1E+04	4.2E-01	No	7.2E-03	No	
Butyltins							mg/kg						
Tributyltin	0	/	36	0%	0.0036	0.0038	1.8E+02	--	--	No	--	No	
Dibutyltin	12	/	36	33%	0.0054	0.0058	1.8E+02	3.8E-02	2.1E-04	No	3.6E-06	No	
Butyltin[6]	7	/	36	19%	0.0038	0.0041	1.8E+02	1.0E-02	5.6E-05	No	9.6E-07	No	
Volatile Organic Compounds							µg/kg						
VOCs	0	/	36	0%	12.5	1580	--	--	--	No	--	No	
Semi-Volatile Organic Compounds							µg/kg						
SVOCs	0	/	36	0%	330	16000	--	--	--	No	--	No	
								Rj	5.8E+01				
								Nij	28				
								1/Nij	3.6E-02				

Acronyms:
SL = Screening Level.
Soil: Lower of DEQ RBC for Occupational Direct Contact or Construction Worker Direct Contact (September 2009 Upc
If RBC not available, EPA Regional Screening Levels (December 2009). Except: for naturally occuring metals,
screening level is not less than background as defined by Washington Department of Ecology for Clark County.
-- = Not Applicable.
COPC = Chemical of Potential Concern.

Variables:
Cij = Maximum detected concentration of compound i in medium j.
Rij = Risk ratio for compound i in medium j (Cij/SL); compound is a COPC if Rij is greater than 1.
Rj = Sum of risk ratios for medium j.
Nij = Number of compounds i detected in medium j.
Rij/Rj = Compound is a COPC if this ratio is greater than 1/Nij.

Notes:
1) SL for 2-methylnaphthalene used as surrogate SL.
2) SL for Benzo(k)fluoranthene used as surrogate SL.
3) SL for arsenic is background. However, if detected above background, Rij calculated fror risk-based concentration of 1.7 mg/kg.
4) Chemicals with frequency of detection of less than five percent were not retained as COP per DEQ risk assessment guidance (DEQ 2000; Section 2.3.2[1]).
5) SL for chromium VI conservatively used.
6) SL for Dibutyltin used as surrogate SL.

Table 2
Summary of Exposure Point Concentrations (EPCs)
Swan Island Upland Facility - OU4

Medium	Location	Chemical	Data Distribution				Concentration				
			Statistical Assessment				Mean	Maximum	90% UCL	EPC	
			Normal	Lognormal	Gamma	Non-Parametric				CT	RME
Soil in mg/kg	0 to 3 feet	Arsenic				90% Chebyshev	4.5	19	9.3	4.5	9.3
		Benzo(a)anthracene	90%KM(%Boot)				1.5	6.5	2.6	1.5	2.6
		Benzo(b)fluoranthene	90%KM(%Boot)				2.0	8.3	3.5	2.0	3.5
		Benzo(a)pyrene			90%KM (Cheb)		2.5	10	6.8	2.5	6.8
		Indeno(1, 2, 3-cd)pyrene	90%KM(t)				1.9	8.1	3.6	1.9	3.6
Soil in mg/kg	0 to 15 feet	Arsenic				90% Student's-t	3.5	19	4.5	3.5	4.5
		Benzo(a)anthracene			90%KM(t)		0.86	6.5	1.5	0.86	1.5
		Benzo(b)fluoranthene			90%KM(t)		1.3	8.3	2.1	1.3	2.1
		Benzo(a)pyrene			90%KM(BCA)		1.4	10	2.2	1.4	2.2
		Indeno(1, 2, 3-cd)pyrene	90%KM(t)				1.1	8.1	1.8	1.1	1.8

Notes:
1. See Appendix A for list of data used.
2. See Appendix C for statistical calculations.
3. EPC = Exposure Point Concentration.
4. UCL = Upper Confidence Limit of the Mean.
5. CT = Central Tendency.
6. RME = Reasonable Maximum Exposure.
7. mg/kg = Milligrams per kilogram.

Table 3
Summary of Human Health Risk-Based Concentrations (RBCs)
Swan Island Upland Facility - OU4

	General Endpoint Effects	Risk-Based Concentrations[1]		
		Occupational - Direct Contact	Construction Worker - Direct Contact and Inhalation	Excavation Worker - Direct Contact and Inhalation
Soil in mg/kg				
Arsenic	Carcinogen	1.7	13	370
Benzo(a)anthracene	Carcinogen	2.7	21	590
Benzo(b)fluoranthene	Carcinogen	2.7	21	590
Benzo(a)pyrene	Carcinogen	0.27	2.1	59
Indeno(1, 2, 3-cd)pyrene	Carcinogen	2.7	21	590

Notes:

1. RBDM Guidance (DEQ, 2003) unless noted otherwise. Default values from table updated September 15, 2009
2. mg/kg = Milligrams per kilogram.

Table 4
Risk Characterization
Swan Island Upland Facility - OU4

Exposure Area	Receptor	Medium	Pathway	Chemical	EPC		RBC	Individual Chemical Excess Risk		Cumulative Excess Risk	
					CT	RME		CT	RME	CT	RME
OU4	Occupational	Soil, 0 to 3 feet, mg/kg	Ingestion, Direct Contact, Inhalation	Arsenic	4.5	9.3	1.7	3E-06	5E-06		
				Benzo(a)anthracene	1.5	2.6	2.7	6E-07	1E-06		
				Benzo(b)fluoranthene	2.0	3.5	2.7	8E-07	1E-06		
				Benzo(a)pyrene	2.5	6.8	0.27	9E-06	3E-05		
				Indeno(1, 2, 3-cd)pyrene	1.9	3.6	2.7	7E-07	1E-06		
										1E-05	3E-05
	Construction Worker	Soil, 0 to 3 feet, mg/kg	Ingestion, Direct Contact, Inhalation	Arsenic	4.5	9.3	13	3E-07	7E-07		
				Benzo(a)anthracene	1.5	2.6	21	7E-08	1E-07		
				Benzo(b)fluoranthene	2.0	3.5	21	1E-07	2E-07		
				Benzo(a)pyrene	2.5	6.8	2.1	1E-06	3E-06		
				Indeno(1, 2, 3-cd)pyrene	1.9	3.6	21	9E-08	2E-07		
										2E-06	4E-06
		Soil, 0 to 15 feet, mg/kg	Ingestion, Direct Contact, Inhalation	Arsenic	3.5	4.5	13	3E-07	3E-07		
				Benzo(a)anthracene	0.86	1.5	21	4E-08	7E-08		
				Benzo(b)fluoranthene	1.3	2.1	21	6E-08	1E-07		
				Benzo(a)pyrene	1.4	2.2	2.1	7E-07	1E-06		
				Indeno(1, 2, 3-cd)pyrene	1.1	1.8	21	5E-08	9E-08		
										1E-06	2E-06
	Excavation Worker	Soil, 0 to 3 feet, mg/kg	Ingestion, Direct Contact, Inhalation	Arsenic	4.5	9.3	370	1E-08	3E-08		
				Benzo(a)anthracene	1.5	2.6	590	3E-09	4E-09		
				Benzo(b)fluoranthene	2.0	3.5	590	3E-09	6E-09		
				Benzo(a)pyrene	2.5	6.8	59	4E-08	1E-07		
				Indeno(1, 2, 3-cd)pyrene	1.9	3.6	590	3E-09	6E-09		
										6E-08	2E-07
		Soil, 0 to 15 feet, mg/kg	Ingestion, Direct Contact, Inhalation	Arsenic	3.5	4.5	370	9E-09	1E-08		
				Benzo(a)anthracene	0.86	1.5	590	1E-09	2E-09		
				Benzo(b)fluoranthene	1.3	2.1	590	2E-09	4E-09		
				Benzo(a)pyrene	1.4	2.2	59	2E-08	4E-08		
				Indeno(1, 2, 3-cd)pyrene	1.1	1.8	590	2E-09	3E-09		
										4E-08	6E-08

Notes:
1. EPC = Exposure Point Concentration; from Table 2.
2. CT = Central Tendency.
3. RME = Reasonable Maximum Exposure.
4. RBC = Risk-Based Concentration; from Table 3.
5. mg/kg = Milligrams per kilogram.
6. Shaded Cell = Cumulative excess risk exceeds acceptable level of 1E-06 for individual chemicals or 1E-05 for cumulative risk.

Table 5
Initial Screening and Evaluation of Technologies for Soil
Swan Island Upland Facility - OU4

General Response Action	Technology	Description	Screening Criteria: Protectiveness/Effectiveness	Long-Term Reliability	Implementability	Implementation Risk	Reasonableness of Cost	Screening Comments
NO ACTION	None	No Action.	--	--	++	++	++	Is not effective, but is retained in accordance with FS rules and guidance as baseline for comparison.
INSTITUTIONAL/ ENGINEERING CONTROLS	Access Restriction	Restrict access with physical, legal, and/or procedural barriers to prevent or control contact with contaminated soil. Examples include controlling site access to authorized personnel, implementing a Soil Management Plan, or deed restriction.	+	0	+	++	++	Potentially applicable and effective. Has lowest cost of applicable alternatives, is relatively easy to implement, and has little or no risks to the public or workers during implementation.
	Monitoring	Laboratory analysis of soil samples to document soil conditions.	NA	NA	+	+	+	Applicable to documenting site conditions and the effectiveness of other technologies.
REMOVAL	Excavation and Off-site Disposal	Contaminated soil would be excavated from the site and disposed of at an appropriate off-site facility.	++	++	0	-	--	Very effective because contaminated soil is removed to a controlled landfill. Excavation complicated by presence of parking lot that is constantly used. Cost would be high and there is nominal potential for exposure of workers and the public.
CONTAINMENT	Capping	Installation of cover to prevent contact with contaminated soil.	+	+	+	+	+	Applicable and effective. Moderate level of long-term effectiveness (requires maintenance). Easily implemented, little risk during implementation, and low cost because existing parking lot can serve as the cap. Institutional controls will be required to address construction worker risk.
IN SITU BIOLOGICAL TREATMENT	Bioventing	Delivering oxygen to contaminated (unsaturated) soils by forced air movement to stimulate biodegradation.	--	0	--	0	0	PAHs not readily amenable to *in situ* biodegradation treatment, with low degradation rates. Does not address arsenic.
	Enhanced Bioremediation (Bioaugmentation, Biostimulation)	Adding nutrients, electron donors/acceptors, selected microbial cultures, or other amendments to enhance bioremediation.	-	0	--	0	-	PAHs not readily amenable to enhanced biodegradation, with low degradation rates. Less suitable for unsaturated soil. Does not address arsenic.
	Land Treatment	Combination of aeration (tilling) and amendments to enhance bioremediation in surface soils.	0	+	--	-	-	PAHs not readily amenable to enhanced biodegradation, with low degradation rates. Not compatible with current and future land use. Not suitable for arsenic.
	Natural Attenuation	Using natural processes to reduce contaminant concentrations to acceptable levels.	--	--	++	++	++	Natural processes likely will not reduce contaminant concentrations to acceptable levels within reasonable timeframe (> 10 years). Does not address arsenic.
	Phytoremediation	Using plants to remove, transfer, stabilize, or destroy contaminants in soil.	--	-	--	0	-	Less effective with PAHs. Land use requirements not compatible with site use. Low PAH concentrations may not be amenable to significant plant uptake.
IN SITU PHYSICAL/ CHEMICAL/ THERMAL TREATMENT	Chemical Oxidation	Chemically converts hazardous contaminants to less toxic compounds by oxidation.	0	+	--	--	--	Less effective for PAHs. Relatively high cost and implementation risk. Delivery to shallow unsaturated soil would be difficult. Does not address arsenic.
	Electrokinetic Separation	Use of electrochemical/electrokinetic processes to desorb and remove metals and polar organics.	0	0	--	-	-	Would require introduction of surfactant or organic modifier. Less effective in shallow soil (would need to include flushing and capture).
	Fracturing	Development of cracks in low permeability or overconsolidated soils to create passageways that increase the effectiveness of other *in situ* processes and extraction technologies.	NA	NA	--	+	+	Applicable only to improve effectiveness of other technologies. Not necessary for site conditions (primarily coarse-grained soil). Not effective in shallow soil.
	Low-Flow Ventilation	Low-flow fan used to create low pressure directly beneath building slabs and prevent vapor migration into buildings.	--	--	--	--	0	Not effective for site conditions consisting of shallow uncovered soil contaminated by semi-volatile compounds
	Soil Flushing	Water (or water containing an additive to enhance contaminant solubility) is circulated through the soil to desorb contaminants, recovered, and treated.	-	-	-	-	-	Less effective for PAHs. Would require surfactant and circulation infrastructure.

Notes:
1. Shading represents technologies that have been eliminated from consideration.
2. Technology Rating: (++) Very Positive; (+) Positive; (0) Neutral; (-) Negative; (--) Very Negative

Table 5
Initial Screening and Evaluation of Technologies for Soil
Swan Island Upland Facility - OU4

General Response Action	Technology	Description	Evaluation Criteria: Protectiveness/Effectiveness	Long-Term Reliability	Implementability	Implementation Risk	Reasonableness of Cost	Screening Comments
IN SITU PHYSICAL/ CHEMICAL/ THERMAL TREATMENT (continued)	Soil Vapor Extraction	Vacuum is applied through vapor extraction wells to create a pressure/concentration gradient that induces vapor-phase volatiles to be removed from soil.	--	--	--	--	-	Not effective for PAHs.
	Solidification/ Stabilization/ Vitrification	Contaminants are physically bound or enclosed within a stabilized mass (solidification and vitrification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).	0	0	-	0	--	Generally used for inorganic contaminants. Would impact site operations. High implementation cost.
	Thermally Enhanced Soil Vapor Extraction Treatment	High energy injection (steam/hot air, electrical resistance, electromagnetic, fiber optic, radio frequency) is used to increase the volatilization rate of semi-volatiles and facilitate extraction.	+	+	--	-	--	Less effective for shallow soil area. High implementation cost.
EX SITU BIOLOGICAL TREATMENT	Biopiles	Excavated soils are mixed with soil amendments and placed in aboveground enclosures and aerated with blowers or vacuum pumps.	-	+	-	-	0	Target compounds (PAHs) not readily conducive to this treatment. Land use requirements are not compatible with site use. Would be combined with excavation. Not effective for arsenic.
	Composting	Excavated soil is mixed with bulking agents and organic amendments to promote microbial activity.	-	+	-	-	0	Degradation of target compounds (PAHs) using microbial enhancement is slow. Land use requirements are not compatible with site use. Would be combined with excavation. Not effective for arsenic.
	Landfarming	Excavated soil is placed in lined beds and periodically tilled to aerate the soil.	-	+	--	-	0	Target compounds not conducive to aeration. Degradation of target compounds (PAHs) by promoting microbial degradation is slow. Land use requirements are not compatible with site use. Would be combined with excavation. Not effective for arsenic.
	Slurry Phase Biological Treatment	An aqueous slurry of soil, sediment, or sludge with water and other additives is mixed to keep solids suspended and microorganisms in contact with the soil contaminants. When complete, the slurry is dewatered and the soil is disposed of.	+	++	--	-	--	Handling of slurry and waste water is unnecessarily complex and expensive. Land use requirements are not compatible with site use. Would be combined with excavation. Not effective for arsenic.
EX SITU PHYSICAL/ CHEMICAL/ THERMAL TREATMENT	Chemical Extraction	Excavated soil is mixed with an extractant which dissolves the contaminants. The resultant solution is placed in a separator to remove the contaminant/extractant mixture for treatment.	+	+	-	-	--	Additional treatment would be required for recovered extractant. Would be combined with excavation. PAHs and arsenic require different approaches.
	Incineration	High temperatures are used to combust (in the presence of oxygen) organic constituents in hazardous wastes.	++	++	0	-	--	Requires off-site transport to distant facility. Is expensive relative to other acceptable treatment/disposal technologies. Would be combined with excavation.
	Soil Washing	Contaminants are separated from the excavated soil with wash-water augmented with additives to help remove organics.	0	+	-	-	--	Less effective with target compounds (PAHs). Additional treatment would be required for wash water. Would be combined with excavation.
	Solar Detoxification	Contaminants are destroyed by photochemical and thermal reactions using ultraviolet energy in sunlight.	-	0	--	-	--	Marginally effective with target compounds, but land use requirements are not compatible with site use. Would be combined with excavation. Not effective for arsenic.
	Thermal Desorption/ Pyrolysis/ Hot Gas Decontamination	Waste soils are heated to either volatilize (desorption and hot gas) or to anaerobically decompose (pyrolysis) organic contaminants. Off-gas is collected and treated.	++	++	-	-	--	Requires off-site transport to distant facility. Is expensive relative to other acceptable treatment/disposal technologies. Would be combined with excavation. Not effective for arsenic.
	Separation	Separation techniques concentrate contaminated solids through physical, magnetic, and/or chemical means. These processes remove solid-phase contaminants from the soil matrix.	-	0	-	-	-	Target compounds cannot be directly separated. Could remove uncontaminated coarse gravels with screening. Would be combined with excavation.

Notes:
1. Shading represents technologies that have been eliminated from consideration.
2. Technology Rating: (++) Very Positive; (+) Positive; (0) Neutral; (-) Negative; (--) Very Negative

Table 6
Estimated Costs For Individual Remedial Action Alternatives
Swan Island Upland Facility - OU4

Technology	Units	Unit Costs	Extended Cost
No Action			
Estimated Total Cost			$0
Capping			
Capital Cost			
Existing Parking Lot	NA	NA	$0
Soil Management Plan	1 l.s.	$10,000	$10,000
Long Term Costs (Present Value*)			
Annual Inspections	30 years	$1,000 /year	$15,400
Cap Maintenance - Standard Parking Lot Main.	NA	NA	$0
Estimated Total Cost (Present Worth)			$25,000
Shallow Excavation and Disposal			
Capital Cost			
Design	1 l.s.	$30,000	$30,000
Pavement Demo/Recycle	13,000 s.y.	$8 /s.y.	$104,000
Storm Sewer Demo/Disposal	430 l.f.	$12 /l.f.	$5,160
Excavation and Disposal	21,000 tons	$45 /ton	$945,000
Backfill and Compaction	15,000 tons	$28 /ton	$420,000
New Storm Sewer	430 l.f.	$45 /l.f.	$19,350
Paving (Base Course and Asphalt Section)	13,000 s.y.	$28 /s.y.	$364,000
Engineering/Oversight/Sampling/Analysis	25 days	$1,600 /day	$40,000
Reporting	1 l.s.	$15,000	$15,000
Soil Management Plan	1 l.s.	$10,000	$10,000
Long Term Costs (Present Value*)			
None	NA	NA	$0
Estimated Total Cost (Present Worth)			$1,953,000
Excavation and Disposal			
Capital Cost			
Design	1 l.s.	$30,000	$30,000
Pavement Demo/Recycle	13,000 s.y.	$8 /s.y.	$104,000
Storm Sewer Demo/Disposal	430 l.f.	$12 /l.f.	$5,160
Excavation and Disposal	60,000 tons	$45 /ton	$2,700,000
Backfill and Compaction	54,000 tons	$28 /ton	$1,512,000
New Storm Sewer	430 l.f.	$45 /l.f.	$19,350
Paving (Base Course and Asphalt Section)	13,000 s.y.	$28 /s.y.	$364,000
Engineering/Oversight/Sampling/Analysis	45 days	$1,600 /day	$72,000
Reporting	1 l.s.	$15,000	$15,000
Long Term Costs (Present Value*)			
None	NA	NA	$0
Estimated Total Cost (Present Worth)			$4,822,000
Arsenic Area Shallow Excavation and Disposal with Capping			
Arsenic Area Shallow Excavation and Disposal			
Capital Cost			
Design	1 l.s.	$30,000	$30,000
Pavement Demo/Recycle	1,700 s.y.	$8 /s.y.	$13,600
Excavation and Disposal	900 tons	$45 /ton	$40,500
Backfill and Compaction	650 tons	$28 /ton	$18,200
Paving (Base Course and Asphalt Section)	1,700 s.y.	$28 /s.y.	$47,600
Engineering/Oversight/Sampling/Analysis	3 days	$1,600 /day	$4,800
Reporting	1 l.s.	$15,000	$15,000
Capping			
Capital Cost			
Existing Parking Lot	NA	NA	$0
Soil Management Plan	1 l.s.	$10,000	$10,000
Long Term Costs (Present Value*)			
Annual Inspections	30 years	$1,000 /year	$15,400
Cap Maintenance - Standard Parking Lot Main.	NA	NA	$0
Estimated Total Cost (Present Worth)			$195,000

Notes:
1. Present value costs calculated with a net annual discount rate of 5%

Table 7
Comparison of Remedial Action Alternatives
Swan Island Upland Facility - OU4

Release Area Alternative	Protective	Balancing Factors																				Score	Rank
		Effectiveness				Long-Term Reliability				Implementability				Implementation Risk				Reasonableness of Cost					
		A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D		
A) No Action	No		-	-	-		-	-	-		+	+	+		0	+	+		+	+	+	2	na
B) Capping	Yes	+		-	-	+		-	-	-		+	+	0		+	+	-		+	+	2	1
C) Shallow Excavation and Disposal	Yes	+	+		-	+	+		-	-	-		-	-	-		+	-	-		+	-3	3
D) Excavation and Disposal	Yes	+	+	+		+	+	+		-	-	+		-	-	-		-	-	-		-1	2

Notes:

+ = The alternative is favored over the compared alternative (score=1)

0 = The alternative is equal with the compared alternative (score=0)

\- = The alternative is less favorable than the compared alternative (score=-1)

na = Not protective, therefore not ranked

	vs Technology			
Technology A		B	C	D
Technology B	A		C	D
Technology C	A	B		D
Technology D	A	B	C	

Table 8
Residual Risk Estimate
Swan Island Upland Facility - OU4

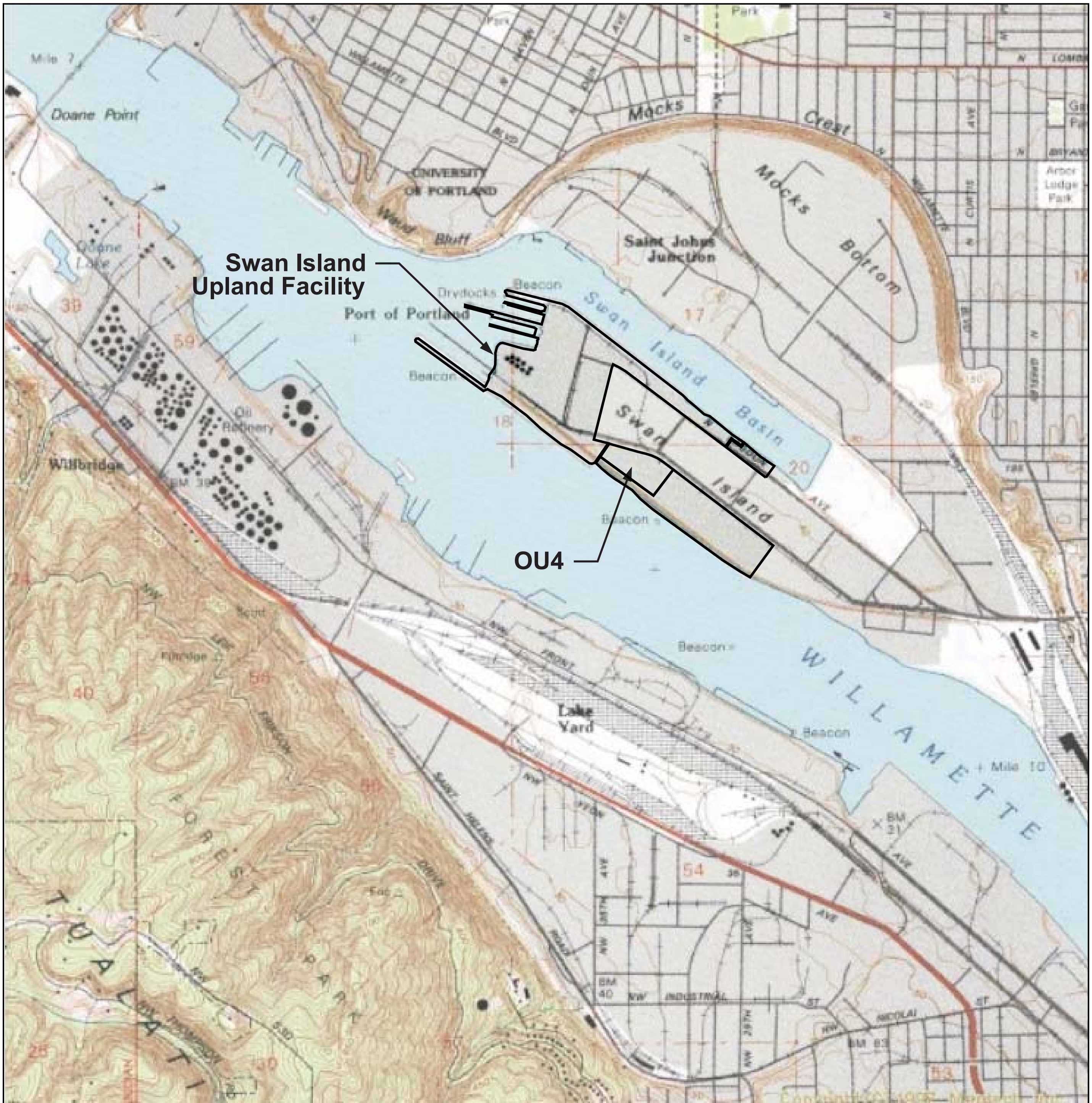
Residual Soil Exposure Point Concentrations

Exposure Area	Location	Chemical	Data Distribution Comments	Concentration, mg/kg Mean	Maximum	90% UCL	EPC CT	EPC RME
Managed Risk	0 to 3 feet	Arsenic	Limited data points	6.9	19	NA	6.9	19
		Benzo(a)anthracene	Limited data points	3.0	6.5	NA	3.0	6.5
		Benzo(b)fluoranthene	Limited data points	4.1	8.3	NA	4.1	8.3
		Benzo(a)pyrene	Limited data points	5.0	10	NA	5.0	10.1
		Indeno(1, 2, 3-cd)pyrene	Limited data points	3.9	8.1	NA	3.9	8.1
	0 to 15 feet	Arsenic	Nonparametric, 90% Chebyshev (Mean, Sd) UCL	4.7	19	11	4.7	10.8
		Benzo(a)anthracene	Normal distribution, 90% KM (t) UCL	1.9	6.5	3.1	1.92	3.1
		Benzo(b)fluoranthene	Normal distribution, 90% KM (t) UCL	3.1	8.3	4.8	3.1	4.8
		Benzo(a)pyrene	Normal distribution, 90% KM (t) UCL	3.3	10	5.3	3.3	5.3
		Indeno(1, 2, 3-cd)pyrene	Normal distribution, 90% KM (t) UCL	2.6	8.1	4.1	2.6	4.1
Residual Risk	0 to 3 feet	Arsenic	Limited data points; maximum detected at background	3.0	3.2	NA	See Note 8	
		Benzo(a)anthracene	Limited data points	0.012	0.016	NA	0.012	0.016
		Benzo(b)fluoranthene	Limited data points	0.011	0.015	NA	0.011	0.015
		Benzo(a)pyrene	Limited data points	0.015	0.025	NA	0.015	0.025
		Indeno(1, 2, 3-cd)pyrene	Limited detections	NA	0.013	NA	0.013	0.013
	0 to 15 feet	Arsenic	Maximum detected at background	2.8	3.5	NA	See Note 8	
		Benzo(a)anthracene	Infrequently detected	NA	0.016	1.5	0.016	0.016
		Benzo(b)fluoranthene	Infrequently detected	NA	0.015	2.1	0.015	0.015
		Benzo(a)pyrene	Infrequently detected	NA	0.025	2.2	0.025	0.025
		Indeno(1, 2, 3-cd)pyrene	Infrequently detected	NA	0.013	1.8	0.013	0.013

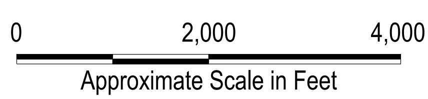
Risk Calculations

Exposure Area	Receptor	Medium	Pathway	Chemical	EPC CT	EPC RME	RBC	Individual Chemical Excess Risk CT	Individual Chemical Excess Risk RME	Cumulative Excess Risk CT	Cumulative Excess Risk RME
Managed Risk	Occupational	Soil, 0 to 3 feet, mg/kg	Ingestion, Direct Contact, Inhalation	Arsenic	6.9	18.7	1.7	4E-06	1E-05		
				Benzo(a)anthracene	3.0	6.5	2.7	1E-06	2E-06		
				Benzo(b)fluoranthene	4.1	8.3	2.7	2E-06	3E-06		
				Benzo(a)pyrene	5.0	10.1	0.27	2E-05	4E-05		
				Indeno(1, 2, 3-cd)pyrene	3.9	8.1	2.7	1E-06	3E-06		
										3E-05	6E-05
	Construction Worker	Soil, 0 to 3 feet, mg/kg	Ingestion, Direct Contact, Inhalation	Arsenic	6.9	18.7	13	5E-07	1E-06		
				Benzo(a)anthracene	3.0	6.5	21	1E-07	3E-07		
				Benzo(b)fluoranthene	4.1	8.3	21	2E-07	4E-07		
				Benzo(a)pyrene	5.0	10.1	2.1	2E-06	5E-06		
				Indeno(1, 2, 3-cd)pyrene	3.9	8.1	21	2E-07	4E-07		
										3E-06	7E-06
		Soil, 0 to 15 feet, mg/kg	Ingestion, Direct Contact, Inhalation	Arsenic	4.7	10.8	13	4E-07	8E-07		
				Benzo(a)anthracene	1.9	3.1	21	9E-08	1E-07		
				Benzo(b)fluoranthene	3.1	4.8	21	1E-07	2E-07		
				Benzo(a)pyrene	3.3	5.3	2.1	2E-06	3E-06		
				Indeno(1, 2, 3-cd)pyrene	2.6	4.1	21	1E-07	2E-07		
										2E-06	4E-06
Residual Risk	Occupational	Soil, 0 to 3 feet, mg/kg	Ingestion, Direct Contact, Inhalation	Arsenic	See Note 8						
				Benzo(a)anthracene	0.012	0.016	2.7	4E-09	6E-09		
				Benzo(b)fluoranthene	0.011	0.015	2.7	4E-09	5E-09		
				Benzo(a)pyrene	0.015	0.025	0.27	5E-08	9E-08		
				Indeno(1, 2, 3-cd)pyrene	NA	0.013	2.7	NA	5E-09		
										6E-08	1E-07
	Construction Worker	Soil, 0 to 3 feet, mg/kg	Ingestion, Direct Contact, Inhalation	Arsenic	See Note 8						
				Benzo(a)anthracene	0.012	0.016	21	6E-10	8E-10		
				Benzo(b)fluoranthene	0.011	0.015	21	5E-10	7E-10		
				Benzo(a)pyrene	0.015	0.025	2.1	7E-09	1E-08		
				Indeno(1, 2, 3-cd)pyrene	NA	0.013	21	NA	6E-10		
										8E-09	1E-08
		Soil, 0 to 15 feet, mg/kg	Ingestion, Direct Contact, Inhalation	Arsenic	See Note 8						
				Benzo(a)anthracene	NA	0.016	21	NA	8E-10		
				Benzo(b)fluoranthene	NA	0.015	21	NA	7E-10		
				Benzo(a)pyrene	NA	0.025	2.1	NA	1E-08		
				Indeno(1, 2, 3-cd)pyrene	NA	0.013	21	NA	6E-10		
										NA	1E-08

Notes:
1. EPC = Exposure Point Concentration.
2. CT = Central Tendency.
3. RME = Reasonable Maximum Exp
4. RBC = Risk-Based Concentration; from Table 3.
5. mg/kg = Milligrams per kilogram.
6. NA = Not applicable; insufficient detected data to calculate mear
7. Shaded Cell = Cumulative excess risk exceeds acceptable level of 1E-06 for individual chemicals or 1E-05 for cumulative risk.
8. Mean and maximum concentration are background. Risk calculation not applicable.
9. See Appendix A for list of data used.
10. See Appendix C for statistical calculations.
11. UCL = Upper Confidence Limit of the Mean.



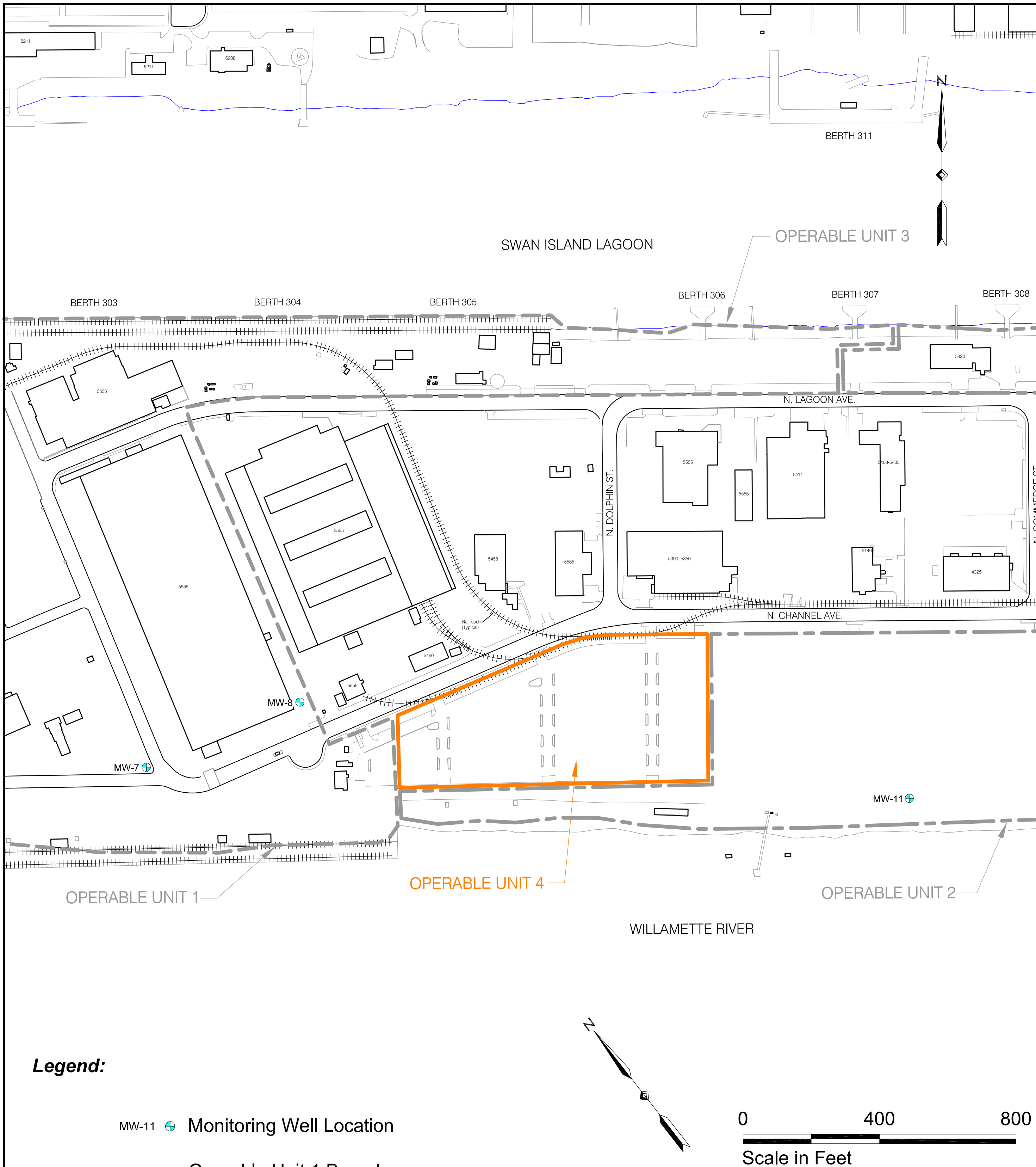
NOTE: Base map prepared from USGS 7.5-minute quadrangles as provided by Topozone. (1990)



Facility Location Map

Risk Assessment, Feasibility Study, and Source Control Evaluation
Swan Island Upland Facility Operable Unit 4
Portland, Oregon

Ash Creek Associates, Inc. Environmental and Geotechnical Consultants	Project Number	1115-11	Figure
	November 2011		1



Legend:

MW-11 ⊕ Monitoring Well Location

Operable Unit 1 Boundary

Operable Unit 2 Boundary

Operable Unit 3 Boundary

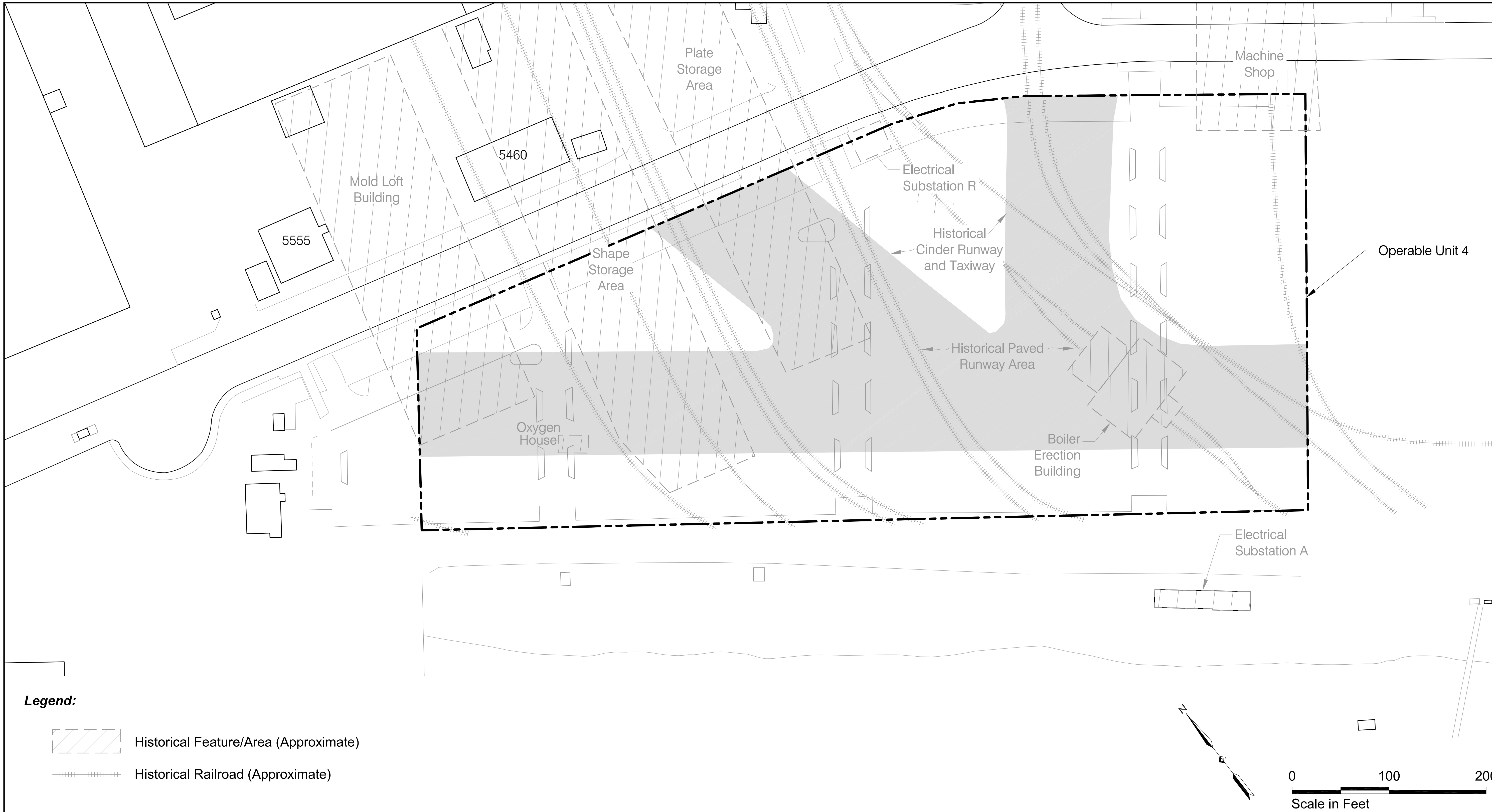
Operable Unit 4 Boundary

NOTE:
1. Prepared from AutoCAD base map received from the Port of Portland in June 2007.

Facility Vicinity Plan

Risk Assessment, Feasibility Study, and Source Control Evaluation
Swan Island Upland Facility Operable Unit 4
Portland, Oregon

Ash Creek Associates, Inc. Environmental and Geotechnical Consultants	Project Number	1115-11	Figure
	November 2011		2



Legend:

Historical Feature/Area (Approximate)

Historical Railroad (Approximate)

NOTES:

1. Prepared from AutoCAD base map received from the Port of Portland in June 2007.

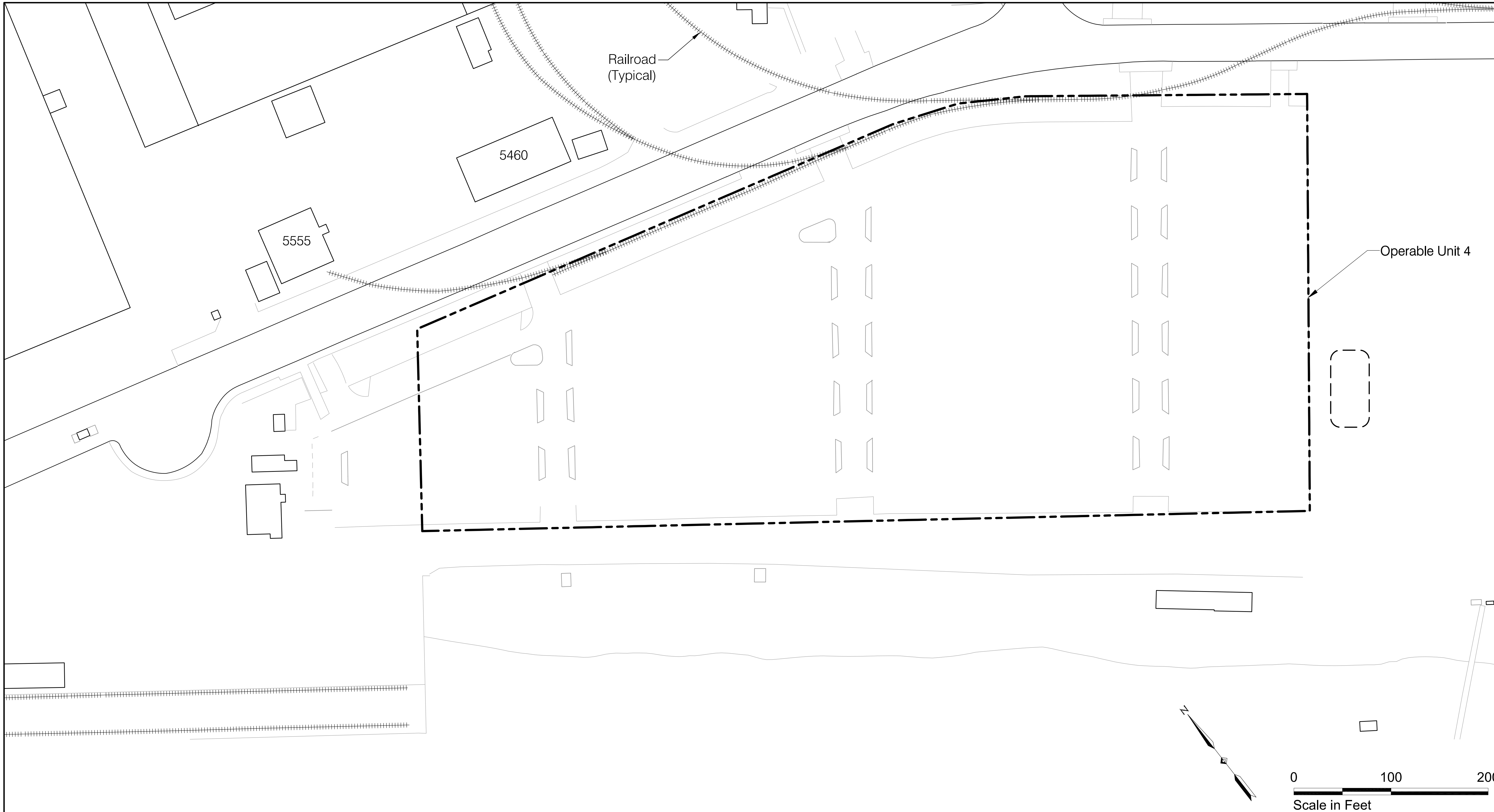
2. Historical from: 1943 Aerial by Ackroyd Photography Photo 23344-7; Airport Layout from The Port of Portland, Portland Harbor Willamette River from South City Boundary to West Oregon Lumber Co's Mill, 1932; Underground System by Port of Portland, Drawing YA 1942 0503; Kaiser Shipyard Layout, 1945; and a Parking Lot Drawing, Existing Topography, YA 77-11 2/11, 1977.

Historical Features

Risk Assessment, Feasibility Study, and Source Control Evaluation
Swan Island Upland Facility Operable Unit 4
Portland, Oregon

Ash Creek Associates, Inc.
Environmental and Geotechnical Consultants

Project Number	1115-11	Figure
November 2011		3



NOTES:

1. Prepared from AutoCAD base map received from the Port of Portland in June 2007.
2. Aerial photograph from from 2010 - Google Imagery. Aerial dated 2008.

Facility Plan

Risk Assessment, Feasibility Study, and Source Control Evaluation
Swan Island Upland Facility Operable Unit 4
Portland, Oregon

Ash Creek Associates, Inc.
Environmental and Geotechnical Consultants

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Legend:

- WR-399 Outfall Location and Designation
- Catch Basin Location
- Inlet Location
- Manhole Location
- DR Drain Location
- STS Location and Flow Direction (Port of Portland)

NOTE:
1. Prepared from AutoCAD base map received from the Port of Portland in June 2007.

Storm Water System

Risk Assessment, Feasibility Study, and Source Control Evaluation
Swan Island Upland Facility Operable Unit 4
Portland, Oregon

Ash Creek Associates, Inc.
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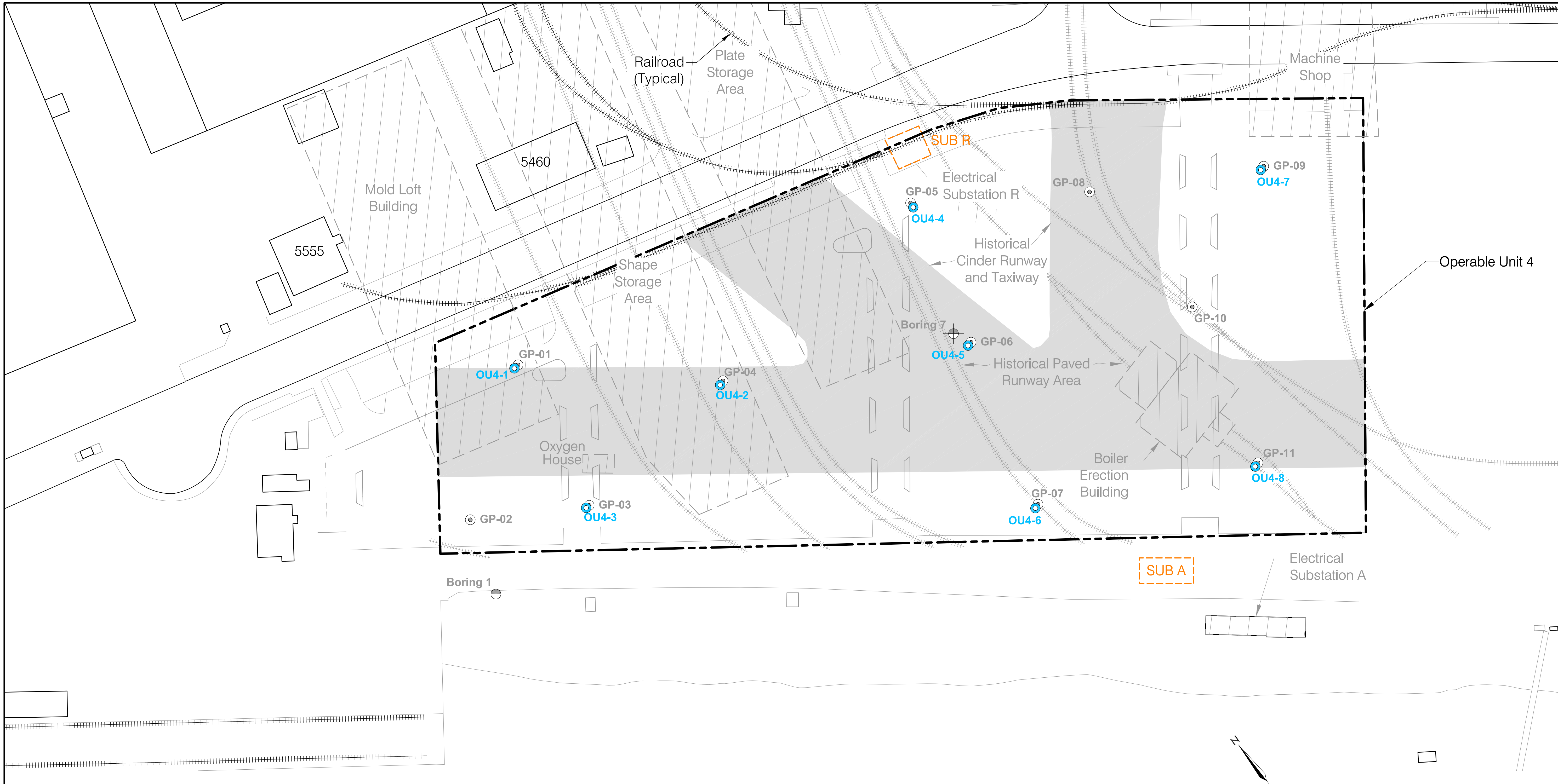

Legend:

OU4-1 Boring Location (2010)

Boring 1 Soil Boring Location (1998)

GP-07 URS Boring Location (2009)

SUB A Kaiser Shipyard Substation Location - 1942 Plan (Locations Approximate)

N E W S Substation soil samples collected at North, South, East, and West corners (5/2007)

Historical Feature/Area (Approximate)

Historical Railroad (Approximate)

NOTES:

1. Prepared from AutoCAD base map received from the Port of Portland in June 2007.

2. Historical from: 1943 Aerial by Ackroyd Photography Photo 23344-7; Airport Layout from The Port of Portland, Portland Harbor Willamette River from South City Boundary to West Oregon Lumber Co's Mill, 1932; Underground System by Port of Portland, Drawing YA 1942 0503; Kaiser Shipyard Layout, 1945; and a Parking Lot Drawing, Existing Topography, YA 77-11 2/11, 1977.

Upland Sample Location Plan

Risk Assessment, Feasibility Study, and Source Control Evaluation
Swan Island Upland Facility Operable Unit 4
Portland, Oregon

Ash Creek Associates, Inc.
Environmental and Geotechnical Consultants

Project Number	1115-11	Figure
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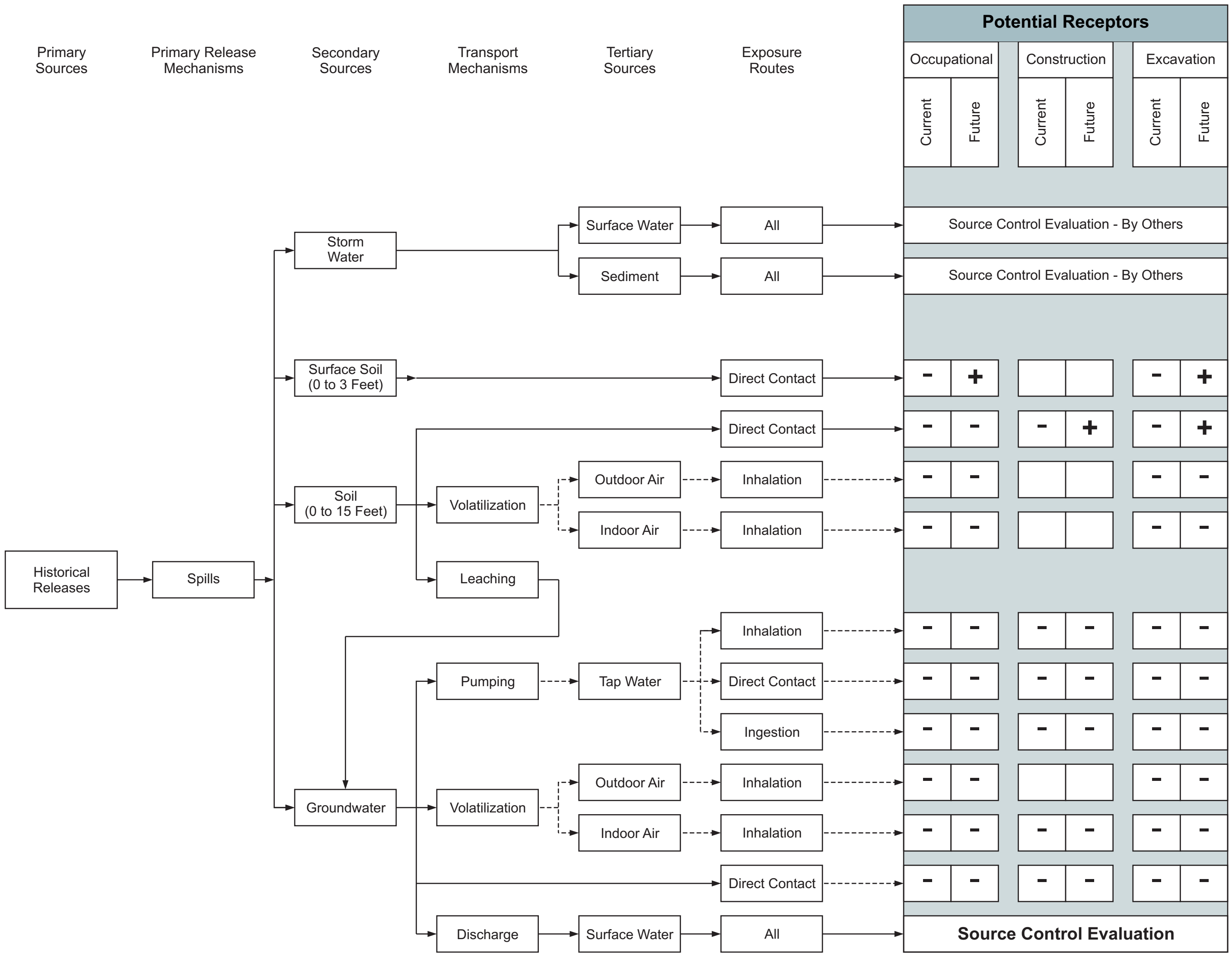

Legend:

+ Primary Exposure Route

- No Exposure Via This Route

Human Health Conceptual Site Model

Risk Assessment, Feasibility Study, and Source Control Evaluation
Swan Island Upland Facility Operable Unit 4
Portland, Oregon

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Project Number	1115-11	Figure
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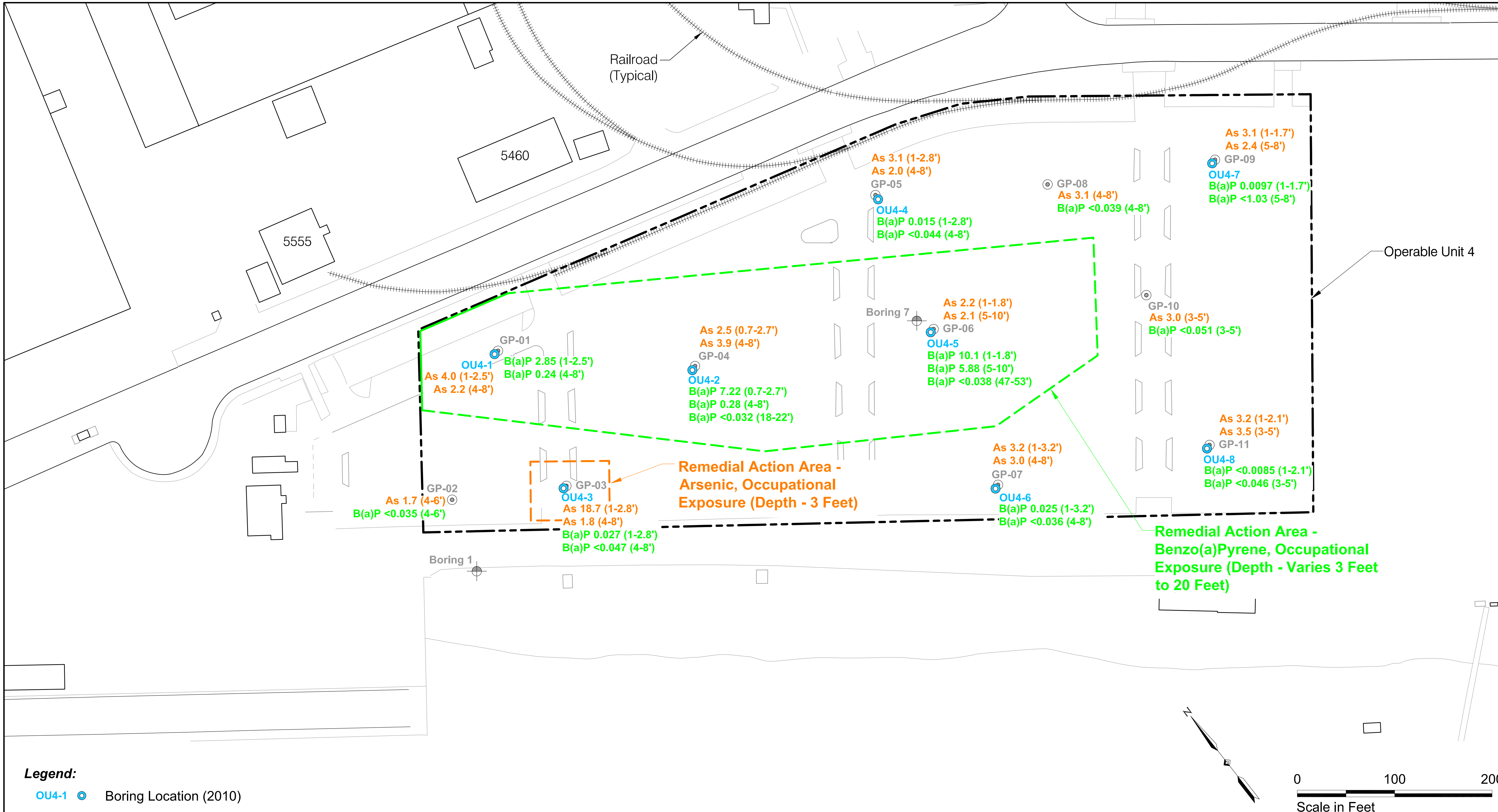

Legend:

OU4-1 — Boring Location (2010)

Boring 1 — Soil Boring Location (1998)

GP-07 — URS Boring Location (2009)

As 1.71 (4-6') — Arsenic Concentration in mg/kg with (Depth) in Feet

B(a)P 2.85 (1') — Benzo(a)Pyrene Concentration in mg/kg with (Depth) in Feet

NOTE:

1. Prepared from AutoCAD base map received from the Port of Portland in June 2007.

Remedial Action Areas

Risk Assessment, Feasibility Study, and Source Control Evaluation
Swan Island Upland Facility Operable Unit 4
Portland, Oregon

Ash Creek Associates, Inc.
Environmental and Geotechnical Consultants

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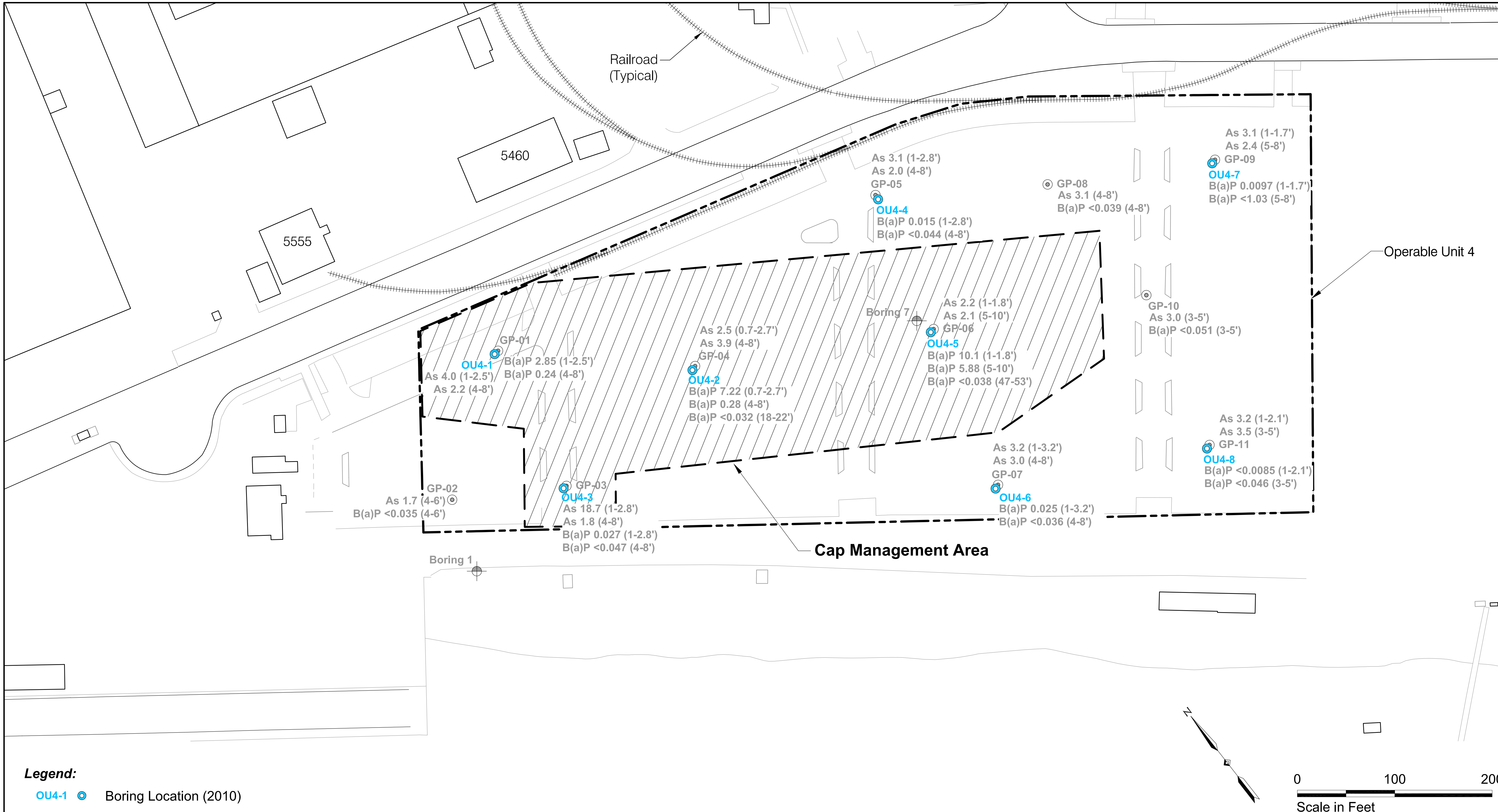

Legend:

- OU4-1 — Boring Location (2010)
- Boring 1 — Soil Boring Location (1998)
- GP-07 — URS Boring Location (2009)
- As 1.71 (4-6') — Arsenic Concentration in mg/kg with (Depth) in Feet
- B(a)P 2.85 (1') — Benzo(a)Pyrene Concentration in mg/kg with (Depth) in Feet

NOTE:
1. Prepared from AutoCAD base map received from the Port of Portland in June 2007.

Cap Alternative

Risk Assessment, Feasibility Study, and Source Control Evaluation
Swan Island Upland Facility Operable Unit 4
Portland, Oregon

Ash Creek Associates, Inc.
Environmental and Geotechnical Consultants

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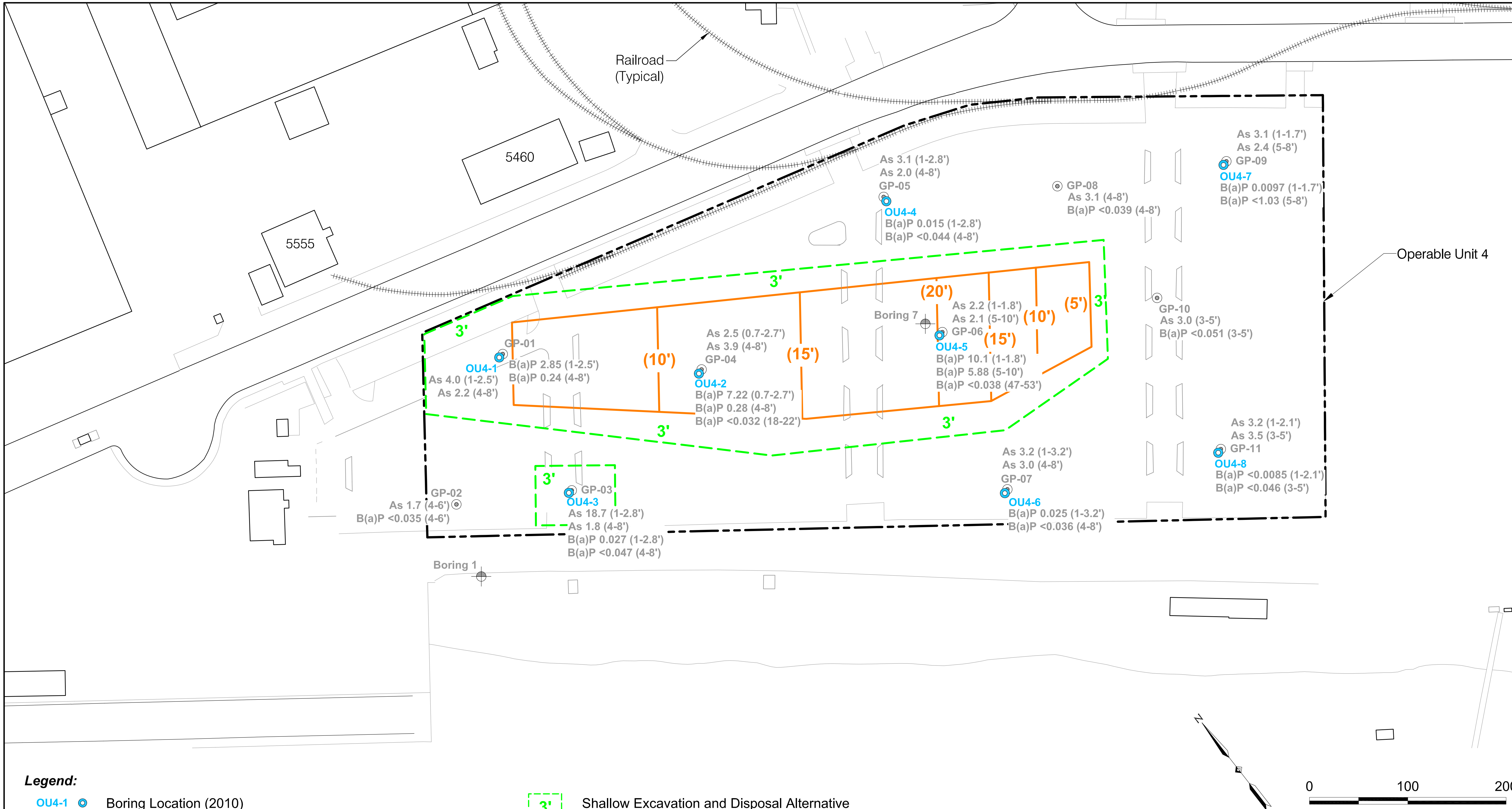
November 2011		9



Legend:

- OU4-1 — Boring Location (2010)
- Boring 1 — Soil Boring Location (1998)
- GP-07 — URS Boring Location (2009)
- As 1.71 (4-6') — Arsenic Concentration in mg/kg with (Depth) in Feet
- B(a)P 2.85 (1') — Benzo(a)Pyrene Concentration in mg/kg with (Depth) in Feet
- 3' — Shallow Excavation and Disposal Alternative (Depth = 3 Feet)
- (5') — Excavation and Disposal Alternative (Approximate Depth Shown in Feet)

NOTE:
1. Prepared from AutoCAD base map received from the Port of Portland in June 2007.

Excavation Alternatives

Risk Assessment, Feasibility Study, and Source Control Evaluation
Swan Island Upland Facility Operable Unit 4
Portland, Oregon

Ash Creek Associates, Inc.
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November 2011		10